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THE MAMMAL FAUNA OF SCHULZE CAVE, EDWARDS COUNTY, TEXAS

WALTER W. DALQUEST, EDWARD ROTH, AND FRANK JUDD

SYNOPSIS: Vertebrate remains from two levels in Schulze Cave, Edwards County, Texas, are analyzed. The younger materials probably date from ca. 5,000 B.P. to 3,800 B.P. The fauna is essentially modern, but the absence of the armadillo collared peccary, ringtail, and rock squirrel is thought to be significant. The older materials probably date from ca. 11,000 B.P. to 8,000 B.P. The mammalian fauna of these Pleistocene sediments includes 62 species, of which 3 are extinct, 19 are not now resident on the Edwards Plateau, and 40 still live in the general area of the cave. Three species have not previously been reported from Pleistocene deposits in Texas: vagrant shrew, eastern chipmunk, and western jumping mouse. Five species of the Schulze Cave local fauna are now found no closer than the southern Rocky Mountains of Colorado and New Mexico. These prefer an alpine meadow habitat, and it is postulated that alpine meadow conditions were present on the High Plains during late Wisconsin time. Other species of the Schulze Cave local fauna are now found no closer than the woodlands of eastern Texas, and it is probable that the woodlands were continuous to the Edwards Plateau in late Wisconsin time.

TABLE OF CONTENTS

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INTRODUCTION

Schulze Cave is located approximately 28 miles northeast of the town of Rock Springs. The entrance is about 0.5 miles east of the dry stream bed shown on the County Highway Map of the Texas Highway Department (1958) as Paint Creek, and approximately 3.8 miles due east of the Rigsby Triangulation Station. The only entrance is a manhole-like opening in the horizontal limestone at the crest of a small, low hill. The opening is usually covered with logs and brush to prevent livestock from falling into the cave.

The cave is of the sinkhole type and probably was formed by solution from a vertical fissure that penetrated two limestone layers of the Upper Cretaceous Edwards formation. The lower, more sandy and less soluble, rock layer forms a narrower part of the shaft (Figure 1) and once supported a shelf of travertine that nearly spanned the sinkhole.

Vertebrate remains were found at three places in the cave: under the opening (Figure 1, A), on a travertine ledge remnant deeper in the cave (B, C), and in a debris accumulation at the bottom (E). At locality A a black humus soil occupies the interstices between the numerous limestone boulders and cobbles. Bones are common, including remains of Indians, opossum, white-tailed deer, cotton rat, wood rat, skunk, and weasel. These are all obviously quite modern, probably only a few hundreds of years old, and are not further dealt with in this report.

At the very bottom of the vertical shaft is a debris cone including some boulders weighing a ton or more. Just above the cone and at the lip of the first lateral chamber is a ledge capped with a yellow travertine deposit that includes the fossilized bones of many animals (Figure 1, E). It represents part of the accumulation of debris in and near the bottom of the shaft. Although the remains are of Pleistocene age, there is no stratigraphic control and they are not dealt with further here.

The old travertine ledge (Figure 1, layers B, C), now a semicircular shelf 6 feet wide, furnishes the collection upon which the present report is based. Here the early Recent deposits (layer B, ca. 7,000 to 3,800 years BP) reached a maximum depth of 6 feet and Pleistocene deposits (layer C, ca. 11,000 to ca. 8,000 years BP) are much thicker.

We interpret the history of the cave as follows. The cave was largely formed before there was any opening to the surface. The

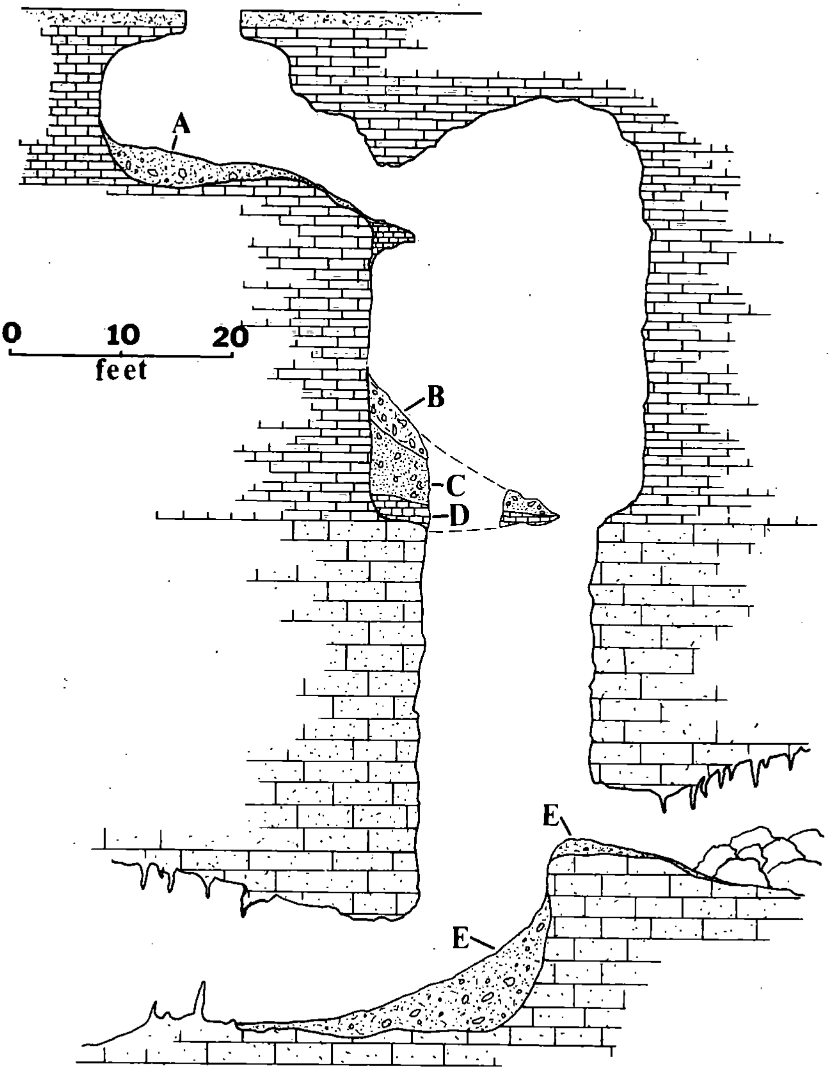

FIGURE 1. Vertical section through Schulze Cave, showing locations of fossil-bearing sediments. A. – Surface detritus below cave opening. B. – Early Recent deposit (7,000 to 3,800 BP). C. – Pleistocene deposits. D. – Travertine Ledge. E. – Bottom detritus, largely from layers B and C.

ledge was formed by carbonate-laden water dripping from the lip of the sinkhole and precipitating as it struck the narrowed portion of the shaft. Only after the ledge was formed was a small opening dissolved in the roof of the entrance room. Soil and organic matter washed into the entrance room and, eventually, down the slope to the lip of the shaft. Soil, pebbles, bones of vertebrates, snail shells, and insoluble matter spalling from the cave, washed over the lip and gathered on the ledge to form the present brown clay-like matrix of layer C.

The opening in the roof of the entrance chamber must have been 18 inches or less in diameter at this time (Pleistocene), for the bones on the ledge are of small animals or, rarely, small bones of larger species. Only in the upper part of layer C are found bones of large size, such as limb bones of grizzly bear or shells of box turtles. Even during the earlier stages of accumulation of the fossils the opening to the cave must have been large enough to admit barn owls, for the birds are almost certainly the source of most of the small vertebrate fossils. The matrix of layer C is mostly a fine-grained, brown, clay-like material rich in carbonate grit. It contains bands of pebbles and scattered fist-sized cobbles, but the materials are otherwise unstratified. Crusts and layers of travertine scattered throughout the deposit probably reflect changes in the contour of the dripstone edge of the lip of the shaft above. Fossils were loosely distributed throughout the clay matrix, and when freshly removed from the matrix, were orange-red in color. Upon drying, the bones became rusty-brown to dull orange in color. Some bones, especially those from deeper in the Pleistocene deposits or those enclosed in white travertine, became white or pale yellow when dried. Many fossils were completely encrusted in gray travertine and only the shape of the resultant pebble suggested that a bone lay within.

The close of this initial period of deposition is marked by the presence of larger limestone fragments and bones imbedded in the clay-like matrix. The opening to the surface must then have been somewhat enlarged. The contact between layer B and layer C is sharp. The upper 4 inches of layer C is transitional with regard to size of inclusions but not in color, texture, or mineralogical nature of sediments. While the mud matrix of layer B did not separate cleanly from the top of layer C, a number of bones lay flat on the top of layer C. When these were exposed a flat surface resulted with no bones or rock fragments passing from one type of matrix into the other. No human remains were noted in this zone where larger bones and cobbles are common, but human activity may have increased the size of the entrance hole in the entrance room. However no trace of such work remains, for the lip of the opening shows only solution marks.

Layer B is of early Recent age. The sediments differ radically from those of layer C. Whereas layer C is a clayey matrix with some limestone fragment inclusions, layer B is composed largely of limestone boulders and cobbles with some interstitial mud matrix. This mud matrix can be easily compressed in the hand into a ball that will crumble with slight pressure. Adhering matrix can be rubbed away from bones or cobbles. In contrast, layer C matrix is so viscous that matrix and bones could be removed only with picks. Bones broke before they could be pulled free from the clinging matrix. Matrix could be sliced from a bone with a knife, but could not be brushed or rubbed away. It did wash away easily after being thoroughly dried and then plunged into cold water.

The layer B material may have accumulated much more swiftly than the layer C sediments, for it contains relatively little fine-grained matrix. As human remains are fairly plentiful in layer B, human activity may have contributed to the accumulation of boulders and cobbles.

The travertine ledge upon which the layer C, and later layer B, sediments gathered, was probably not very thick. The actual thickness cannot be determined, but was greatest beneath the overhanging lip of the shaft. The weight of the layer C sediments, augmented by the weight of the masses of rock of layer B, overburdened the ledge. The central portion, some 6 feet in diameter, collapsed and fell into the shaft, leaving only a thin lip suspended over the shaft, and an inner rim that was supported by the lower limestone member (Figure 1). The collapse of the ledge furnished a vertical section through the sediments, and subsequent erosion exposed the bones.

Most of the small mammals were probably brought to the site as prey of barn owls. The appearance of the skulls is similar to the appearance of skulls in modern barn owl pellets, and the kinds of small mammals recovered are like those that barn owls eat today. Some animals undoubtedly entered the cave voluntarily, while many others must have simply fallen into the manhole-like opening of the cave. Bones of larger mammals were either washed into the cave or brought in by wood rats.

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We are deeply grateful to Kenneth Schulze for calling our attention to Schulze Cave, assistance in excavation, and numerous other favors during our work, and we have named the cave for him. We wish to thank Pierce Hoggett, owner of the land on which Schulze Cave is located, for permission to work in the cave. Claude Hibbard, of the University of Michigan, aided us in many ways and confirmed or corrected the identifications of many specimens. E. R. Hall of the University of Kansas aided in identifications of some of the carnivores and gave us free access to the collections in his charge. E. E. Bray of the Research Department, Socony Mobil Oil Company, furnished carbon 14 dates. Frank Schitoski and Bobby Westmoreland aided in excavations in the cave and gave valuable help in the laboratory study of the fossils. Many other persons assisted in the collecting and washing of the matrix from Schulze Cave but we wish especially to thank the following for working in the bitter weather and dangerous conditions in the cave: Walter Nelson, Timmothy Ann Sloan, Rose Carpenter, Peggy Dalquest, Pinky Eustice, Nancy Scott, Wayne Bailey, Jean Lewis, and William Kilpatrick. All funds for the present investigation were furnished by Midwestern University and approved by the Faculty Research Committee.

STRATIGRAPHY

Layer B deposits were completely unstratified. Limestone boulders and cobbles made up the bulk of the deposit. The fossilized bones were found in matrix filling the interstices. Human remains were scattered throughout this layer. Included were six skulls and quantities of post-cranial materials. These extended nearly to the bottom of the layer but were more common in the upper part. One skull was approximately 12 inches out from the wall of the shaft and 3 inches beneath the surface of the deposit. This must have been among the last bones to be buried in the ledge sediments. Beneath the cheek of this skull was a small quantity of charcoal. A carbon 14 determination by Socony-Mobil Laboratories gave a date of 3,826 ± 208 years BP (lab. no. SM 893). This, then, is the date when the ledge collapsed. The steep surface of the remaining sediments, and the large opening in the ledge, prevented further accumulation on the ledge. After this time nearly all falling bones or rocks passed through the opening in the ledge and fell to the bottom of the shaft.

Layer C was first excavated to a depth of 18 inches in January, 1965. The portion removed and studied is designated C1. A portion of the pelvis of a grizzly bear, found 9 inches beneath the surface of layer C1, was submitted to Socony-Mobil Laboratories for dating. Other bones, almost certainly from the same bear, were scattered from 6 to 18 inches beneath the top of layer C1. The date, 9,680 ± 700 years BP (lab. no. SM 807) indicates a late Pleistocene age for this layer.

In January 1966, another 18 inches was removed (designated layer C2). Many more travertine ledges were found in the C2 layer than in C1. In the lower 6 inches of the deposit, beneath some thick and hard ledges, the matrix changed lithologically. It became less viscous and was lemon-yellow in color rather than brown or orange. Bones were pale yellow when wet, and difficult to see in the matrix. Few large bones were found, but small bones were plentiful and especially well-preserved. Teeth sometimes appeared to be silicified. These yellow sediments continued to the bottom of layer C2, where excavation ended.

Bones of white-tailed deer collected at the 36-inch level (bottom of layer C2) proved too low in collagen content for carbon 14 dating, and had to be supplemented by nearly 2 pounds of bones collected from the 24- to 30-inch levels. The combined sample, which can only be described as from the lower half of layer C2, was determined by Isotopes Inc., of Westwood, New Jersey, as 9,310 ± 310 years BP (sample number I-2741A).

The date of 9,680 ± 700 BP, from the middle of layer C1, is within the limit of experimental error of the 9,310 ± 310 BP date for the lower part of layer C2. Carbon dates are not available for the top of C1 or the bottom of C2. Appreciable time must have elapsed, however, to permit the accumulation of the compact clay sediments and fossils, and the formation of the many travertine ledges and crusts. Moreover the two layers contain some evidence of faunal succession. If an average deposit of 1 inch of sediment per 100 years be allowed, the top of C1 was deposited approximately 8,000 years BP and the bottom of layer C2 approximately 11,000 years BP.

In contrast to the compact nature of the layer C sediments, layer B consists of relatively loose materials, and gives evidence of rapid deposition. The carbon date of 3,800 years BP for the top of layer B seems quite reasonable. In the absence of datable material from the bottom of layer B we can only estimate the age of this level. We think all of layer B accumulated in 1,000 years or less. The cave must have been sealed to outside access for about 3,000 years, from 8,000 years BP to 5,000 years BP or later, on the basis of the disconformity between the layer B and layer C deposits, the nature of the sediments, the difference in preservation of bones, and difference in the two faunas. Moreover if bones from the 9- and 30-inch levels of layer C gave almost the same date, it is scarcely conceivable that sediments above layer C could represent 5,000 years of deposition.

EXTANT EDWARDS PLATEAU FAUNA

The Edwards Plateau has been heavily overgrazed by livestock, especially by sheep and goats. Although areas of woodland and meadow are numerous, the land has been reduced generally to a semidesert of thin, stony soil and bare rock (Tharp, 1952).

On the basis of trapping and observation, small mammals such as insectivores and mice are rather scarce, though medium-sized mammals are common. White-tailed deer abound. On the 40-mile drive from Shulze Cave to the town of Junction, our headquarters during the excavation work, we commonly counted 50 to 150 deer in an afternoon. Carcasses of skunks (*Mephitis, Conepatus*) and armadillos, run over on the highway, were such a common sight as to become monotonous. Fox squirrels are common in wooded areas. Smaller carnivores, especially raccoon, ringtail, and gray fox, are plentiful, but the larger species have been exterminated. Even the coyote and bobcat have been greatly reduced in numbers to protect the sheep and goats upon which the economy of the region is based.

Limestone hills, cliffs, and talus offer seemingly ideal habitat for wood rats, but we found little sign of these mammals and took none, even though three species of wood rats have been reported to occur on the Edwards Plateau. In contrast the large rock squirrels, *Spermophilus variegatus,* is common in the cliffs and talus where wood rats would be expected to live. Two genera of pocket gophers have been recorded from the Edwards Plateau, but we found no gopher mounds in Edwards County, where in fact there is little soil deep enough to support gophers.

As a result of human activities, the present ecological conditions on the Edwards Plateau must be highly unnatural and transitional. It is unfortunate that the record of the successive mammalian faunas, as preserved in Schulze Cave, stops abruptly some 3,800 years ago. It would be interesting to have a more accurate record of the changes occuring after occupation of the land by Europeans.

Considering only Edwards, Kimble, Mason, Menard, Uvalde, Real, Kerr and Medina counties, a species list (Table 1, col. 2) was compiled from specimen records at Midwestern University and published sources, especially Hall and Kelson (1959) and Davis (1960). Throughout this report we have followed Hall (1965) in arrangement of species and use of common and scientific names, except for the use of *Odocoileus* rather than *Dama* for the generic name of the deer.

Table 1. Edwards Plateau and Schulze Cave Faunas

	Modern	Layer B	Layer C1	Layer C2
Didelphis marsupialis	X	1[3 4]		
Sorex cinereus			11[4]	5[4]
Sorex vagrans			1	
Blarina brevicauda			79	83
Notiosorex crawfordi	X	26	62	37
Scalopus aquaticus			3	3
Aello megalophylla	X			
Myotis velifer	X	67	58	128
Myotis cf. *M. evotis*			8	16
Pipistrellus subflavus	X			4
Eptesicus fuscus	X[1]		1	
Nycteris borealis	X			
Nycteris cinereus	X[1]			2
Nycticeius humeralis	X			
Plecotus townsendii	X			
Antrozous pallidus	X			
Tadarida brasiliensis	X			
Homo sapiens	X	6	1	2
Dasypus novemcinctus	X			
Sylvilagus floridanus	X	9[3]	137	246
Sylvilagus audubonii	X			
Lepus cf. *townsendii*				1
Lepus californicus	X	3	2	5
Tamias striatus			12	17
Spermophilus mexicanus	X			1
Spermophilus spilosoma				2
Spermophilus variegatus	X			
Cynomys ludovicianus	X		2	3
Sciurus niger	X			
Thomomys umbrinus	X	1	2	16
Geomys bursarius	X	33	48	89
Perognathus merriami	X	223	435	135
Perognathus hispidus	X	158	462	114
Dipodomys ordii			5	2
Castor canadensis	X			
Oryzomys plaustris			1	
Reithrodontomys montanus	X	25	83	52
Reithrodontomys megalotis			1	6
Reithrodontomys fulvescens	X	7	13	26
Peromyscus maniculatus			79	145

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[1] Occurrence not, to our knowledge, supported by specimens from the Edwards Plateau, but the Plateau is within their known geographic range.

[2] Now extirpated, but certainly or probably present in historic times.

[3] Selected specimen encountered in excavating (all others are jaws and skulls washed from a 100-pound sample of matrix).

[4] Figures indicate number of catalogued specimens in Midwestern University collection of fossil vertebrates.

TABLE 1. EDWARDS PLATEAU AND SCHULZE CAVE FAUNAS (continued)

	Modern	Layer B	Layer C1	Layer C2
Peromyscus leucopus	X	14	168	153
Peromyscus boylii	X	2	85	43
Peromyscus pectoralis	X	43	170	22
Baiomys taylori	X	X	18	3
Onychomys leucogaster[1]	X	43	129	42
Sigmodon hispidus	X	303	732	176
Neotoma floridana	X		8	7
Neotoma micropus	X	32	137	200
Neotoma albigula	X	2	18	
Microtus ochrogaster pinetorum	X		169	367
Synaptomys cooperi			5	7
Zapus princeps			1	9
Canis latrans	X[1]	1[2]	6	2
Canis cf. *C. lupus*	X[2]			1
Canis familiaris	X	2[3]		
Vulpes vulpes			3	4
Vulpes velox				7
Urocyon cinereoargenteus	X			
Ursus americanus	X[2]		1	1
Ursus horribilis	X[2]	1	1	
Bassariscus astutus	X			
Procyon lotor	X			
Nasua narica	X			
Mustela erminea			1	
Mustela frenata	X	1[3]	1	
Mustela vison	X			
Taxidea taxus	X[1]			1
Spilogale putorius	X		10	6
Mephitis mephitis	X	1[3]	2	2
Conepatus mesoleucus	X		1	1
Felis onca	X[1]	1	1	
Felis concolor	X[2]			1
Felis pardalis	X[3]			
Felis yagouaroundi			3	2
Felis rufus	X		4	3
Elephas cf. *columbi*				1
Tayassu tajecu	X			
Odocoileus virginianus	X	1[3]	3	4
Antilocapra americana[1]	X			
Bison bison[2]	X			
Bison sp.			1	1
Equus sp.			1	1

SCHULZE CAVE EARLY RECENT FAUNA

Column 3 of Table 1 lists the numbers of specimens of each species catalogued from layer B. Certainly no part of layer B is Pleistocene. Every species in its fauna has occurred on the Edwards Plateau in historic time. Its relative antiquity is suggested by the absence of several species that ought to be present if the fauna were modern.

The occurence of *Didelphis* is based on a single jaw identified in the field and subsequently lost or misplaced. The *Sylvilaqus* material contains a skull that is definitely *floridanus,* but the other eight individuals are not specifically identifiable. Many of the listed *Geomys* jaws are without teeth, and it is possible that some of these actually are *Thomomys.* A partial humerus and ulna of a large, stout canid cannot be matched with available specimens of the gray wolf and may belong to the domestic dog. If so, the specimens are so stout that they must represent a strain of dog different from that represented by the listed skull.

The bear material includes the broken skull, lower jaw, and shaft of the humerus of a cub. Most of the milk teeth have been lost, and the M^1 is just erupting. The crown is exposed but unworn. This tooth is much larger than M^1 of any 12 skulls of *Ursus americanus amblyceps* Baird available from New Mexico. This is the subspecies of bear that once ranged onto the Edwards Plateau. The tooth from Schulze Cave is even larger than the M^1 of two Boone and Crocket Club record-size black bears, *Ursus americanus pugnax* Swarth, from Alaska. For this reason the bones are referred to the grizzly bear.

Though every species listed for the layer B fauna is also present in the modern fauna of the Edwards Plateau, not all occur today in the vicinity of the cave (e.g. *Onychomys, Geomys*). Many common modern species are not present in layer B. In the case of many of the larger mammals, this is probably the result of the random nature of the cave as a bone trap, as well as the influence of ecological conditions in the vicinity of the cave. Absence of the woodland vole, *Microtus pinetorum,* suggests that no areas of lush, cool grasses and weeds were present nearby.

The absence of some forms from the layer B deposits may be significant from the zoogeographic point of view. The modern armadillo, *Dasypus novemcinctus,* is not present. This myopic, blundering creature, if present in the area when the layer B sediments were accumulating, would almost certainly have fallen into the cave trap. The carcass of a single armadillo, upon disintegration, would scatter its hundreds of tiny scutes throughout the deposit, and each scute is distinctive and easily recognized. We found no such scutes and feel reasonably sure that the armadillo was absent during the 4,000 to 7,000 year BP period. Lundelius (1967) points out that armadillo remains are known in Texas only from very late archeological sites and that the species probably did not reach the state until later than 1,000 A.D.; he considers (footnote, p. 13) Patton's (1963) record from the brown clay unit of Miller's Cave to be a Recent intrusive.

The absence of the collared peccary, *Tyassu tajacu,* is also of significance. Peccaries are fairly common on the Edwards Plateau at the present time and only heavy hunting keeps them from becoming numerous. Many extinct peccaries (*Platygonus, Mylohyus*) are on record from caves and other late Pleistocene deposits of Texas, but no *Tyassu.* Frank (1964) notes remains of *Tyassu* from Zesch Ranch Cave, Mason County, and Pictograph Cave, Hill County, presumably from late Recent deposits, but Lundelius (1967) states that *Tyassu* has not been found in any archeological sites in central Texas.

Also significant is the absence of the rock squirrel, *Spermophilus variegatus,* from level B. Rock squirrels are virtually confined to the shelter of steep banks, rocks, and talus. Their remains are easily identified. We find no records of the rock squirrel in the numerous cave faunas of southern Texas listed by Frank (1964) except the four archeological sites: Centipede Cave, Damp Cave, Mosquito Cave and Coontail Spin Shelter, all in Val Verde County. The rock squirrel was probably resident in the Trans-Pecos area since the late Pleistocene, but seems to have moved eastward onto the Edwards Plateau only later than 4,000 years BP.

The absence of procyonids in Shulze Cave is most puzzling. *Nasua* may be a rare, recent addition to the Edwards Plateau fauna, but the raccoon is a common form at present, and numerous Pleistocene records exist from southern Texas. The absence of the raccoon from layer B may be due to chance.

This can scarcely be said of the ringtail, *Bassariscus.* Ringtails prefer rocky areas. They climb readily and make their homes in caves and crevices. Ringtails are abundant on the Edwards Plateau. If they were resident in the vicinity of Schulze Cave in the early Recent, their remains would be expected in the layer B fauna. They are often found in late Recent cave faunas, and Bob Slaughter, of Southern Methodist University, informs us (Pers. comm.) that *Bassariscus* is present in virtually all of a number of very late Recent archeological site faunas he studied. Semken (1961) lists *Bassariscus* from the late Pleistocene Red Fill unit of Longhorn Cave, Burnet County. We know of no other Pleistocene records. Frank (1964) lists the ringtail from the Barton Springs site, Travis County, with a carbon date of 2,000 years BP, also from Centipede Cave, Damp Cave, and Coontail Spin Shelter, all archeological sites in Val Verde County. Val Verde County is west of the Edwards Plateau, in the Chihuahuan biotic province. The mammals there have their affinites with species of the Trans-Pecos region of Texas. It is noteworthy that the three Val Verde County records come from the same archeological sites where the rock squirrel, *Spermophilus variegatus*, has been recorded. Probably the ringtail, like the rock squirrel, moved eastward to occupy the Edwards Plateau only in very late Recent time.

None of the human bones found in layer B were articulated. Many are leached and light in weight. At least eight individuals are represented, the youngest a child with the second molars just erupting, the oldest a person without a tooth remaining in the lower jaw and with all alveoli completely closed by bone.

We believe the bodies were thrown or placed in the entrance chamber of the cave and the bones of the disarticulated skeletons later worked down the slope and fell onto the ledge. This accounts for the leached condition of the bones and their scattered positioning in the matrix.

PLEISTOCENE FAUNA (LAYERS C1 AND C2)

Columns 4 and 5 of Table 1 list the numbers of catalogued specimens from each of the two Pleistocene layers. The numbers are not strictly comparable. A specimen might be a partial skeleton or a nearly complete skull in one instance, or an isolated tooth in another. Nevertheless the numbers do give a fair idea of the relative numbers of individuals of the species occuring in each layer.

Approximately 3,000 pounds of matrix were worked from each layer. Fossils were more common in the upper layer, C1. The number of catalogued specimens from this layer is 3,334, versus 2,544 from layer C2. The total, 5,878, does not include thousands of isolated teeth and post-cranial elements that have not been studied in detail.

In the species accounts, referred specimens are listed in brief form in the first paragraph. For the smaller forms, specimens are usually listed simply as "skulls" or "jaws." Skulls are all more or less fragmentary, but are so listed if the palate and an appreciable part of the rostrum or cranium is present and some teeth remain in the maxillaries. Jaws may be maxillaries or mandibular rami, complete or fragmentary, but do retain at least one tooth. Where pertinent, more complete description is given. Catalogue numbers in parenthesis refer to the Midwestern University collection of fossil vertebrates. For each species we have tried to furnish the following data: basis of identification, present geographic range, nearest approach to Schulze Cave at the present time, ecological preference, and other late Pleistocene occurences in Texas.

Sorex cinereus — MASKED SHREW

Layer C1, 1 skull, 10 jaws (7255). Layer C2, 1 skull, 4 jaws (7326).

The masked shrew is easily recognized by several jaw and tooth characters. The skull has 5 unicuspid teeth on each side, vs. 4 in *Cryptotis* and *Notiosorex*. The lower jaws are exceedingly small and slender compared with other shrews of the Schulze Cave local fauna. In seven jaws from layer C1, the P_4-M_3 are present and not greatly worn. The crown length of these teeth, measured with an accurately calibrated occular micrometer, ranges from 3.53 to 3.76 mm, with a mean of 3.6 mm. This is a trifle smaller than the teeth of specimens trapped in northern New Mexico, but is like Recent specimens from Michigan.

The present range of S. *cinereus* includes most of artic and subartic America and extends southward in the southern Rocky Mountains to north-central New Mexico. At its nearest approach to Schulze Cave, the masked shrew lives in the spruce forests and mountain meadows of the Canadian Life-zone of Taos and San Miguel counties, New Mexico. At elevations comparable to Schulze Cave, S. *cinereus* is found no nearer than Nebraska.

In northern New Mexico *cinereus* perfers dense ground cover of grass or herbaceous vegetation, cool preferably damp ground, and soft loamy soil. If these conditions are present the gross environment, i.e., spruce forest, aspen forest, or broad clearings, is secondary in importance. Preferred habitat is the lush herbaceous vegetation in alder or willow thickets by small streams. The fact that the shrews are trapped under logs in open spruce forest, without understory vegetation, shows that they wander from preferred habitat. Almost invariably we found *Sorex vagrans* in the same habitat, but *vagrans* was more common in damp areas and less common in dry sites.

The only previous records of *cinereus* from the late Pleistocene of Texas are from the Howard Ranch Local Fauna (Dalquest, 1965) and the Ben Franklin Local Fauna (Slaughter and Hoover, 1963). Both sites are in northern Texas.

Sorex vagrans — VAGRANT SHREW

Layer C1, 1 jaw (7256).

The skull of S. *vagrans* is larger and stouter than the skull of S. *cinereus,* but the difference is not great. The great difference in the size of the teeth and lower jaws in the two species is striking. The lower jaws of *vagrans* can scarcely be confused with the lower jaws of *cinereus.* S. *vagrans* lower jaws are approximately the size of lower jaws of *Cryptotis parva* and *Notiosorex crawfordi.* The length of P4-M3 in the specimen from Schulze Cave is 4.3 mm, versus a maximum of 3.76 mm for S. *cinereus.* The ramus of C. *parva* is relatively stout with a convex ventral border whereas the ramus of *vagrans* is more slender and has a concave ventral border. The notch in the articular condyle of *Notiosorex* is very deep, almost "V"-shaped (see Hibbard and Taylor, 1960).

S. *vagrans,* as the species is currently accepted, ranges over western North America from northern Alaska to central Mexico. Wandering shrews are found today as close to Schulze Cave as the mountains in Otero County, south-central New Mexico. In early Recent times they occurred a trifle closer, in Eddy County, New Mexico (Findley, 1965). In the far west, *vagrans* may occur at low elevations but in the eastern part of its range it is found only in alpine habitat. In the United States the wandering shrew does not occur as far east as Schulze Cave, or farther east than the mountains of central New Mexico and Colorado. In Mexico S. *v. orizabae* lives in the high mountains at the eastern edge of the Mexico Plateau.

The Schulze Cave specimen is the first definite record of S. *vagrans* from the Pleistocene of Texas. Dalquest (1967) referred a jaw fragment from the much older Slaton Quarry Local Fauna questionably to *vagrans.*

Blarina brevicauda — SHORT-TAILED SHREW

Layer C1: 11 skulls, 68 jaws (7258). Layer C2: 13 skulls, 70 jaws (7327). This was the commonest shrew in the Schulze Cave Local Fauna.

Remains of this large, stout shrew cannot be confused with any other form in the Schulze Cave Local Fauna. The jaws show considerable variation in size in both the C1 and C2 layers, but the average size is the same in both. In 50 specimens (30 from C1, 20 from C2) the molar series (M_1-M_3), is complete and unworn or but slightly worn. The measurements of these teeth, taken with an occular micrometer along the lingual border of the jaw, range from 4.1 to 5.0 mm, with a mean of 4.53 mm. The difference in size between the largest and smallest jaws from both layers suggests that two species might be involved, but the measurements do not show a bimodal distribution and indicate a single rather variable population. All but the smallest specimens are too large for the small races found in southeastern Texas today; their average size is similar to the average of *B. b. carolinensis*, from northeastern Texas, Oklahoma, and Kansas.

The short-tailed shrew is confined today to the eastern United States, from southern Canada to Florida and east of the Rocky Mountains. It is found no closer to Schulze Cave than the woodlands of extreme eastern Texas. The nearest record is Aransas County (*B. b. plumbea*). *Blarina* has been recorded from most well-studied late Pleistocene microvertebrate faunas of Texas. Patton (1963) found *B. brevicauda* in the very late Pleistocene Miller's Cave Local Fauna. Lundelius (1967) maps occurences in Llano County, on the Edwards Plateau, and other Pleistocene localities.

B. brevicauda is primarily a woodland shrew but does inhabit grasslands. We took specimens in prairie habitat in Franklin County, Kansas, in dense cover of grass and weeds where the ground was soft and damp. In Texas *Cryptotis* is most common in similar sites.

Cryptotis parva — LEAST SHREW

Layer C1: 1 skull, 13 jaws (7257). Layer C2: 6 jaws (7328).

Skulls of *Cryptotis* are easily identified by the 4 unicuspid teeth on each side. Lower jaws are separable from those of *Sorex vagrans* by the convex ventral margin, and from those of *Notiosorex* by the shallow notch in the articular condyle.

Hall and Kelson (1959) show the range of the least shrew extending over much of the Edwards Plateau, including Edwards County. This range extension results from the inclusion of a broad area on both sides of a specimen record from Del Rio, in the Rio Grande Valley. Davis (1960) shows the range more correctly as lying entirely east of the Edwards Plateau. We do not understand why *Cryptotis* does not occur on the Edwards Plateau today, for it lives in even more arid, open country in the Texas Panhandle. Nevertheless, it has been found in nearly all counties east of the plateau, as well as north and south, but never on or west of the Edwards Plateau. The early Recent fauna (layer B) of Schulze Cave contained no *Cryptotis* remains.

The least shrew specimen from Del Rio probably belonged to a population that ranges or once ranged westward up the valley of the Rio Grande. Davis (1960) gives records from Frio County and several other sites, all approximately 100 miles east of Schulze Cave. *C. parva* has been found in most late Pleistocene microvertebrate faunas of Texas, including the Miller's Cave Local Fauna of Llano County, on the Edwards Plateau.

C. parva, like most shrews, prefers dense ground cover where the atmosphere is humid, the soil soft, and where vegetation obscures the light and furnishes cover from predacious birds. *Cryptotis* also occurs in arid, almost desert, conditions when cover is suitable.

Notiosorex crawfordi — DESERT SHREW

Layer C1: 5 skulls, 57 jaws (7259). Layer C2: 4 skulls, 33 jaws (7329). The desert shrew is second in abundance to *Blarina* in the cave fauna.

Skulls of *Notiosorex* are identified by the presence of only 3 unicuspid teeth on each side. Lower jaws are identified by the deep notch in the articular condyle as figured by Hibbard and Taylor (1965). Even without these details, jaws and teeth of the desert shrew stand out by reason of the lesser amount of red pigment on the tooth crowns compared to teeth of other shrews.

Schulze Cave is within the present-day range of the desert shrew and the species has been taken on the Edwards Plateau in Kerr County. The desert shrew is the only shrew represented in the early Recent, layer B, fauna of Schulze Cave. Patton (1963) did not report *Notiosorex* from Miller's Cave, but Semken (1961) found it in Longhorn Cavern in Burnet County. Lundelius (1967) lists other records.

The desert shrew is considered a rare mammal, but recent reports suggest that it may be fairly common in suitable habitat. Although its microecology, may be highly specialized, the species occurs primarily in arid brushland with cover of rocks, junipers, mesquite, cactus, and other shrub growth. It seems to have lived in the Schulze Cave area throughout the period of deposition represented by layers B, C1 and C2.

Scalopus aquaticus — Eastern Mole

Layer C1: 3 jaws (7260). Layer C2: 1 jaw, 2 isolated teeth (7330).

The scanty material available seems identical to modern specimens of *Scalopus aquaticus* from northern Texas.

The eastern mole ranges from the eastern edge of the Rocky Mountains eastward over the United States. It has been taken on the Edwards Plateau in Mason County, but not to the south or east, or within 60 miles of Schulze Cave. Moles must have ranged over much of Texas in the late Pleistocene, for *Scalopus* is known from most late Pleistocene microvertebrate faunas, including Miller's Cave on the Edwards Plateau (Patton, 1963). Moreover relict populations exist in the Trans-Pecos region of far western Texas (*S. a. texanus*) and northern Chihuahua (*S. montanus*). The Schulze Cave moles fill in part of the gap between the known range of *S. a. alleni* of southeastern Texas and the relict populations to the west.

In north-central Texas eastern moles are found in the sandy, deep soils of river valleys, out well onto the desert-like plains of the Panhandle and Permian Basin. They do not occur on the firm Permian clay soils away from the streams, and consequently have geographic ranges of dendritic pattern. Level land that might, in the late Pleistocene, have had soil deep enough to support the burrowing activities of moles is present about a half-mile from Schulze Cave. This is probably near the extreme of the hunting range of the owls that presumably brought the few specimens to the cave.

Myotis velifer — Cave Myotis

Layer C1: 58 jaws (7261). Layer C2: 3 skulls, 125 jaws (7331).

Jaws and teeth of *M. velifer* are readily separated from other living species of American *Myotis* by their large size. None of the Schulze Cave specimens are so large and stout, or have such large teeth, as the extinct *M. magnamolaris* from the late Pleistocene (20,000 years BP) Laurbach Cave local fauna.

Bat guano formed great heaps in the lower chambers of Schulze Cave and we expected bat remains to be abundant in the fossil-bearing matrix. Instead, bat remains were relatively uncommon and disappointing in their lack of variety. The Edwards Plateau is within the known range of *M. velifer*, which is probably limited more by cave-producing rock formations, such as gypsum and limestone, than by climate or vegetation.

In Texas, the big-eared bat, *Plecotus townsendi*, and the Brazilian free-tailed bat, *Talarida brasiliensis*, are usually found in caves that shelter the cave myotis. Neither species was found in the fossil deposits of Schulze Cave.

Patton (1963) reports *M. velifer* as common in the late Pleistocene Miller's Cave local fauna, on the Edwards Plateau, and Frank (1964) lists other records from caves in southern Texas.

Myotis cf. M. evotis — LONG-EARED MYOTIS

Layer C1: 8 jaws. Layer C2: 1 skull, 15 jaws.

All these specimens seem referable to a single species of relatively large *Myotis*. Jaws and teeth are smaller than those of *M. velifer* but larger than those of *M. lucifugus*. The skull closely resembles the skull of *M. evotis*, and differs from the skull of *M. thysanodes*. The jaws and molars, however, are slightly smaller than those of *M. rectidentis* (M_1-M_3 3.5 – 4.0 mm, mean 3.6 mm, versus 3.7 – 4.05 mm in *rectidentis*). In the Schulze Cave bats the canine is smaller than illustrated in *rectidentis* (Choats and Hall, 1967) and the P3 is not so crowded and reduced in size. Until the relationships of *rectidentis* are better understood, it seems best to refer the Schulze Cave specimens to *M.* cf. *evotis*, the species they most closely resemble among living myotises.

The long-eared myotis has not been found closer to the Edwards Plateau than the mountains of southwestern New Mexico, but its general range suggests that it will eventually be found in the Trans-Pecos region, at least. Both *M. volans* and *M. thysanodes* are recorded from the Trans-Pecos region.

Pipistrellus subflavus — EASTERN PIPISTRELLE

Layer C2: 4 jaws (7333).

Lower jaws of *Pipistrellus* are easily separated from those of *Myotis* by the presence of 2 rather than 3 premolars. In *P. subflavus* the distance from the canine to the first molar is greater than the length of the second molar; in *P. hesperus* it is less. The well-preserved jaws from Schulze Cave are *P. subflavus*.

The eastern pipistrelle is the only species of bat that lives in Schulze Cave today. A specimen was found in January, 1966, apparently in hibernation, in one of the cave's lower chambers. It must have entered the small spaces among the covering of logs and brush that protected the opening. The canyon bat, *P. hesperus*, has been taken in the Rio Grande Valley at the mouth of the Pecos River, not far to the west of Edwards County, but never on the Edwards Plateau.

P. subflavus ranges through eastern Mexico and from the Edwards Plateau and Texas Panhandle northward to the Great Lakes. It is curious that specimens were found in the deepest layer thus far excavated and in the modern fauna but not in the sediments between. This constitutes the first record of the species from the late Pleistocene of Texas.

Eptesicus fuscus — Big Brown Bat

Layer C1: 1 lower jaw (7263).

The large size and distinctive dentition of *Eptesicus fuscus* permits ready identification. It cannot be confused with any other species in North America.

The geographic distribution of the big brown bat includes most of Central America, all of the United States, and part of Canada. Because it visits caves, especially in winter, its presence in the Schulze Cave local fauna is not unexpected. Patton (1963) found the species common in the late Pleistocene deposits of Miller's Cave on the Edwards Plateau.

Nycteris cincereus — Hoary Bat

Layer C2: 2 jaws (7334). These are right and left rami with the teeth in the same stage of wear. Although no point of contact remains between the two bones, they probably came from the same individual.

The jaws of the hoary bat are recognized by the distinctive dentition and short, curved ramus. The jaws from the cave deposit match the jaws of the living species almost exactly.

N. cincereus is a migratory species that summers in the northern United States and Canada as far as Hudson Bay, and at high elevations farther south in the United States. It spends the winter in the southern United States and Mexico. It has not been taken on the Edwards Plateau but has been found short distances to the east and west as well as north. We find no record of the hoary bat from the Pleistocene of Texas. It is a tree-inhabiting species that ordinarily does not enter caves. Most bones found in caves probably represent prey of barn owls.

Homo sapiens — Man

Layer C1: 1 incisor (7264). Layer C2: 2 upper molars (7335). The incisor was washed from matrix from layer C1, with no special information as to its provenance. It might well have come from the very uppermost part of the layer. The crown is white and fresh. The roots are orange and partially mineralized. Its appearance is almost exactly like that of some other bones from layer C1.

The situation of the two molars is quite different. They were taken from a sack of yellow matrix noted as coming from the very lowest level excavated in layer C2. Other bones in the same sack of matrix were of jumping mice (*Zapus*), chipmunks (*Tamias*) and other Pleistocene forms. The crowns of the teeth are deep amber in color and appear to be mineralized as are other teeth from the yellow matrix. The teeth are from a child. They had not erupted from the jaw and root formation was not completed. The crowns are perfect and beautifully preserved.

The absence of artifacts in the cave deposits is rather surprising. We did find one flint point in the upper zone of level B, along with the abundant human remains from this layer. We found no worked stone in the materials washed and screened from layers C1 and C2. Postdepositional burial is unlikely on the basis of undisturbed crusts and layers of travertine above the remains. The age of the zone where the human teeth were found is estimated to be approximately 11,000 years BP.

Sylvilagus floridanus — EASTERN COTTONTAIL

Layer C1: 2 skulls (7265, 7266), 135 jaws (7267), hundreds of isolated teeth, skull fragments, and post-cranial elements (7268). Layer C2: 246 jaws (7336), hundreds of isolated teeth, skull fragments, and post-cranial elements (7337).

Both *Sylvilagus floridanus* and *S. audubonii*, the desert cottontail, are resident on the Edwards Plateau and have been taken in Edwards County. *S. nuttallii*, Nuttall's cottontail, lives in the mountains of New Mexico, where other members of the Schulze Cave Local Fauna are now found. All three species were considered in identifying the present collection.

The great majority of the nearly 400 available jaws belong to young or very young cottontails, probably brought to the cave as prey of owls. A number of good specimens, palates and lower jaws with all or most of the teeth in an excellent state of preservation, were probably trapped by falling into the entrance hole of the cave.

We found, as have other workers, that though size and pattern of cheek teeth of the several species of cottontails show average differences, they overlap broadly. Pettus (1956) reported that "In

S. *floridanus* the posterior and lingual borders of the third lower pre-molar meet at more of a right angle than in S. *audubonii* where those surfaces curve more gradually into one another." We found no difference between *audubonii* and *floridanus* in this character.

Pettus also reported that the mental symphysis extended farther posteriorly in S. *floridanus* than in S. *audubonii,* but recognized that this was an average difference only. While generally true, we note that the symphysis extends farther in large *audubonii* than in small *floridanus* and suspect that this character is correlated with size of skull and jaws.

S. *audubonii* is distinctly smaller than S. *floridanus,* but only a few Schulze Cave specimens could be identified on this basis. Most jaws could not be clearly assigned to either *floridanus* or *audubonii.* S. *audubonii* also differs from *floridanus* in having much larger, more inflated audital bullae. No rabbit skulls from the cave had the bullae attached. Approximately 40 isolated bullae of adult cottontails were identified by Mrs. Rose Carpenter, a graduate student, and none belonged to *audubonii.* The present geographic range of *audubonii* includes the Edwards Plateau and northward and westward. In northern New Mexico the species ranges to considerable elevation on the mountain slopes, but it is replaced at higher elevations by S. *nuttallii.* On geographic grounds we would expect *audubonii* to have lived in the vicinity of Schulze Cave in the late Pleistocene, but cannot demonstrate that it did so.

Separation of S. *floridanus* from S. *nuttallii* is also difficult. The two species are of about the same size. The audital bullae of S. *f. chapmani,* the race of *floridanus* now living in the vicinity of Schulze Cave, is smaller than the audital bullae of S. *n. pinetis,* the race of *nuttalli* now living in northern New Mexico. The difference is less than between *floridanus* and *audubonii.* Isolated bullae could not be identified.

The mandibular ramus of *nuttallii* from New Mexico, between the base of the incisors and the cheek teeth, is more slender than in old or young *floridanus.* The lower incisors are smaller and narrower. In 10 adult *nuttallii* from New Mexico the distance across the lower incisors, measured just below the tips, ranges from 4.7 to 5.1 mm in 9 jaws and measures 5.4 in the other. Of 25 adult *floridanus,* this distance measured 5.4 mm in 5 and more than 5.4 mm in the other 20. The presumably adult lower jaws from Schulze Cave had heavy rami and large incisors, like *floridanus.*

Direct comparison with Recent specimens of *floridanus* discloses no significant difference between them and the Schulze Cave specimens. The cave rabbits may average slightly larger than specimens of the living animal from north-central Texas. Because the cave cottontails cannot be separated from *floridanus,* and we have no proof that any other species is represented in the collection, we refer the entire series to *floridanus.* Probably 90% of the jaws and all of the isolated teeth and bones other than audital bullae are not specifically identifiable.

S. *floridanus* ranges over much of Mexico and the United States east of the base of the Rocky Mountains, and northward to southern Canada. It inhabits brushy cover and the edges of clearings in woodlands from the tropics of southern Mexico to New England and the Great Lakes. It extends over most of Texas, and over the western half of the state is sympatric with S. *audubonii.*

There are many records of *Sylvilagus* from the late Pleistocene of Texas, including many cave faunas (Frank, 1964). Most reports are of the genus only, or list S. *audubonii* and S. *floridanus* together on the presumption that a collection of fossils of any size will include both forms.

Lepus californicus — BLACK-TAILED JACKRABBIT

Layer C1: 1 complete femur, 1 complete humerus, additional post-cranial material (7269). Layer C2: 2 lower jaws, 3 maxillaries, skull fragments (7338).

Cheek teeth of *Lepus californicus, L. alleni,* the antelope jackrabbit, and *L. townsendii,* the white-tailed jackrabbit, are extremely similar, but the lower jaws of *alleni* are more elongate than those of the other two species, especially in the diastemal region. The ramus between the base of the incisors and the first premolar (P_3) of *alleni* is longer, more slender and delicate. If lower jaws of the three species are lined up with symphyses, bases of incisors and foramina parallel, the P_3 of *alleni* is farther posterior than in the other species, approximately opposite the P_4 of *californicus.* On the basis of this character the jaws from layer C2 are not *alleni.* We found teeth of *townsendii* to average larger than teeth of *californicus* but with considerable overlapping. No reliable method of separating lower jaws of these two forms could be devised.

Limb bones of *L. townsendii* and *L. alleni* are larger and distinctly longer than those of *L. californicus.* Skeletons of *californicus* with skulls and teeth as large as in a skeleton of *townsendii* of similar age had humeri and femora at least 20% shorter and more slender.

Skeletons of *californicus* with skulls as broad and teeth as large (though skulls were considerably shorter) than equivalent skeletons of *alleni* also had limb bones 20% shorter. The great difference in size of *townsendii* as compared with *californicus* is primarily of bulk of body. The greater difference in size of *alleni* as compared to *californicus* is elongation and bulk of body. The limb bones from layer C1 are of the *californicus* type.

L. californicus ranges through the western half of the United States and much of Mexico to the eastern border of the Great Plains. It is found in all of Texas except the woodlands of the eastern margin of the state and is a common resident of the Edwards Plateau.

The preferred habitat of the black-tailed jackrabbit is open grasslands or openings in brushland. It avoids cover except in the warmer hours of the day when it prefers to crouch in a form in the light shade of a bush or the margin of a clump of brush. The humidity at the entrance of Schulze Cave doubtless promoted growth of vegetation that jackrabbits tend to avoid. Moreover a frightened jackrabbit dashing to the margin of the entrance hole could doubtless leap across the opening, for the animals are capable of jumping much greater distances. In contrast, a cottontail rabbit under the same circumstances woud probably fall into the cave trap. This, we suppose, accounts for the relative scarcity of jackrabbit remains in the cave fauna. Patton (1963) found jackrabbit remains rare in Miller's Cave, in Llano County. *L. californicus* or *Lepus* sp. that are probably also *californicus* have been recorded from most well-studied vertebrate microfaunas of Pleistocene age from Texas.

Lepus cf. *townsendii* — WHITE-TAILED JACKRABBIT

Layer C2: 1 isolated lower P3 (7339), measuring 4.8 x 3.6 mm. The tooth is relatively enormous. It is longer, wider, deeper and has broader valleys on the labial side than any teeth of *L. californicus, L. alleni* or *L. townsendii* available to us.

Disregarding *Lepus othus* and *L. arcticus,* both from the remote arctic region, the largest American hare is *L. alleni* and allied forms, such as *L. gaillardi.* Vorhies and Taylor (1933) give the average weight of 61 specimens as 8.2 pounds. The size of *L. alleni* is primarily of body. The skull, though elongated, is slender and the teeth are relatively small. The lower P3 seems unusually small and averages no larger than in the black-tailed jackrabbit, *L. californicus.* Certainly the large tooth from Schulze Cave is not *alleni.*

L. townsendii averages larger than *californicus,* has a larger skull and larger teeth. In several specimens we examined the size difference is slight with much overlapping. We found no specimens in the collections at the University of Kansas Museum of Natural History with the lower P3 as large as the fossil specimen, but several approached it in size, and the resemblance was much closer than in any of a greater number of *L. californicus* studied.

Either the tooth belongs to an extinct, undescribed species of *Lepus* or is from an unusually large specimen of *L. townsendii*. The latter treatment seems most conservative at this time. *L. townsendii* ranges from Kansas northward and westward over the Great Plains and northwestern United States and much of Canada. It extends southward in the southern Rocky Mountains to north central New Mexico, where a number of other elements of the Schulze Cave local fauna now find their nearest approach to the Edwards Plateau. On geographical grounds the tooth might well represent *townsendii*.

Tamias striatus — EASTERN CHIPMUNK

Layer C1: 9 good lower jaws, 2 fragmentary lower jaws, 1 fragmentary upper jaw (7270). Layer C2: 6 good lower jaws, 3 fragmentary lower jaws, 6 good maxillaries, 2 fragmentary maxillaries, isolated teeth (7340).

The presence of *Tamias* in the Shulze Cave local fauna was one of the most surprising discoveries of the present study. Most out-of-range forms in the cave fauna now live in northern New Mexico or eastern Texas, but the eastern chipmunk, today approaches Edwards County most closely in southwestern Arkansas, more than 400 miles to the northeast.

Eutamias minimus, the least chipmunk, and *E. quadrivittatus*, the Colorado chipmunk occur in northern New Mexico, along with the jumping mouse, masked shrew, vagrant shrew and other Rocky Mountain elements of the Schulze Cave local fauna. *E. quadrivittatus*, especially, ranges eastward and occurs in open country at low elevations. These are the forms we would have expected at Schulze Cave. Instead the eastern genus, *Tamias*, was present, and from the number of specimens and their distribution through both layer C1 and C2, it was long a common resident of the vicinity of the cave.

Tamias has never been recorded in Texas as a living mammal, although records from southwestern Arkansas suggest that it might occur in extreme northeastern Texas. There are no previous Pleistocene records of *Tamias* from Texas, either, and in view of its occurrence in Schulze Cave, it might be well to reexamine some reported specimens of small ground squirrels, such as *Spermophilus spilosoma.*

In his recent review of Pleistocene records of *Tamias,* Ray (1965) refers all of them to *T. striatus,* except for the newly-described *T. aristus* from Georgia. We have compared the Schulze Cave specimens with skulls and jaws of *striatus* from Arkansas and can find no differences. The Schulze Cave specimens are definitely referable to *striatus* and provide no basis for racial distinction.

With *T. striatus* a known, common resident of Edwards County in the late Pleistocene, we must speculate that this population on the Edwards Plateau was then continuous with the remainder of the range of the species in southeastern United States. Probably much of central and eastern Texas was occupied by chipmunks at that time. It is difficult to understand why *Tamias* no longer occurs in eastern Texas. Much of the country there seems to offer suitable habitat for chipmunks.

Spermophilus mexicanus — MEXICAN GROUND SQUIRREL

Layer C2: 1 isolated upper molar (7341).

The single available tooth can be matched almost exactly with teeth of modern S. *mexicanus* from northern Texas. It is much too large for a tooth of S. *tridecemlineatus.* We are unable to distinguish between teeth of S. *mexicanus* and S. *richardsonii* (Sabine), but the latter species is found no closer to Schulze Cave than northwestern Colorado and the Dakotas.

The Mexican ground squirrel is the only small species of *Spermophilus* extant on the Edwards Plateau. It occurs in the deeper-soiled fields and terraces along stream valleys but seems nowhere common. It has probably existed on the Edwards Plateau since the late Pleistocene.

Suprisingly few Pleistocene records of *Spermophilus mexicanus* exist. Dalquest (1965) found *mexicanus* or *richardsonii* in Hardeman County, Texas, and Stephens (1960) reported *richardsonii* from a Pleistocene site in Oklahoma. These could just as likely pertain to *mexicanus.* Frank (1964) cites an unpublished Pleistocene record of *mexicanus* from Texas, and Lundelius (1967) reports the species from Zone 1 (uppermost) deposits of Rattlesnake Cave, in Texas. Some of the numerous records of *Citellus* sp. may pertain to S. *mexicanus.*

S. *mexicanus* is abundant in early Recent shelters of ancient man, in marked contrast to its scarcity or absence on Pleistocene sites not occupied by man. Frank (1964) cites a number of records from caves in western Texas, all associated with human dwellings and probably brought to the caves as food.

Spermophilus spilosoma — SPOTTED GROUND SQUIRREL

Layer C2: 1 palate, 1 maxillary (7342), both in a good state of preservation.

The spotted ground squirrel is the smallest member of its genus found in Texas. Separation of jaws and teeth of this species from the Mexican ground squirrel is easy, for the latter is much larger. Jaws and teeth of the thirteen-lined ground squirrel, S. *tridecemlineatus,* are intermediate in size between *mexicanus* and *spilosoma.* Isolated teeth are sometimes difficult to assign to either *tridecemlineatus* or *spilosoma.* When reasonably complete jaws are available, as in the present instance, *spilosoma* is marked by smaller teeth, shorter tooth-rows, and smaller jaws. The present specimens are referable to *spilosoma,* not *tridecemlineatus.*

Neither *spilosoma* nor *tridecemlineatus* lives on the Edwards Plateau at the present time, but both are found nearby. S. *tridecemlineatus* occurs in more humid grasslands to the east of the Edwards Plateau and *spilosoma* in the more sandy country to the west and south. On the sandy soil of stream valleys *spilosoma* may extend its range eastward even into woodlands, as it has done in north-central Texas. We know of no habitat suitable for *spilosoma* in the immediate vicinity of Schulze Cave now, but the presence of *Dipodomys ordii* and other sand-loving species in the fauna attests the presence of such habitat in the late Pleistocene.

We would have expected *tridecemlineatus* in the Schulze Cave Local Fauna but we obtained no evidence of it. As the entire collection contains but one tooth of S. *mexicanus* and two specimens of S. *spilosoma,* the absence of *tridecemlineatus* may be due to chance.

The present geographic range of *spilosoma* includes much of central Mexico and central United States north to South Dakota. It covers most of western Texas eastward, in northern Texas, to the Red River, and in southern Texas to the coast of the Gulf of Mexico. It includes the valley of the Rio Grande. We know of no specimens taken on the Edwards Plateau.

Pleistocene records of *spilosoma* are few. This is due largely to the uncertainty in separating *spilosoma* from *tridecemlineatus* on the basis of the isolated teeth and other poor material usually available. Dalquest (1962a) lists *spilosoma* from Foard County in northern Texas, and Harris and Findley (1964) list it from Bernalillo County, New Mexico. Frank (1964) cites records of *spilosoma* from Centipede Cave and Damp Cave, both human occupation sites in western Texas.

Some of the Pleistocene specimens listed simply as *Spermophilus* or *Citellus* sp. are probably referable to *spilosoma.*

Cynomys ludovicianus — BLACK-TAILED PRAIRIE DOG

Layer C1: 1 upper molar, 1 incisor (7271). Layer C2: 1 skull (7343), 1 palate (7344), 1 lower jaw (7345) with complete dentition.

The prairie dog material from layer C2 was associated. All was washed from a single sack of yellow matrix from the lower part of layer C2. Preservation is good and the shape and relative size of the upper molars show that the species present in the cave was the black-tailed, not the white-tailed, *C. gunnisoni.* The latter species occurs in northern New Mexico and a related form has been found as a fossil in a Pleistocene site in Lublock County, Texas (Dalquest, 1967). The presence of the white-tailed prairie dog at Schulze Cave would not be unexpected.

The black-tailed prairie dog ranges from centrel Texas, southern New Mexico and adjacent Mexico and Arizona, northward over the Great Plains to Southern Canada. There are old records from the Edwards Plateau, but we know of none from Edwards County or nearby. Despite rumors of a prairie dog town in Menard County, the nearest definite record is from Mason County (Hollister, 1916).

The prairie dog has been taken in most Pleistocene sites in Texas where small mammals were collected carefully. Its geographic range was more extensive in the late Pleistocene than at present (Lundelius, 1967). The rocky brushland in the environs of Schulze Cave today would not support prairie dogs, but apparently did so in the late Pleistocene.

Thomomys umbrinus — SOUTHERN POCKET GOPHER

Layer C1: 1 isolated upper and 1 isolated lower premolars (7272). Layer C2: 1 palate, 15 isolated premolars (7346).

Few pocket gopher jaws from Schulze Cave contain teeth, and we hesitate to refer toothless jaws even to genus. Premolars of *Thomomys* differ from those of *Geomys* in the shape of the lingual and labial valleys: U-shaped in *Geomys*, V-shaped in *Thomomys.* The upper premolar of *Geomys* has no enamel on its posterior face; the posterior face of the upper premolar of *Thomomys* is enamel-covered (Merriam, 1895). The upper molars of both genera are simple dentine structures with enamel on both front and back faces. In the lower molars *Thomomys* has enamel on both front and back faces, *Geomys* only on the posterior face. Thus molars lacking enamel on the posterior face are *Geomys* inferior molars, but we can not reliably separate upper and lower molars of *Thomomys* or the upper molars of *Geomys* from molars of *Thomomys*. Isolated molars with enamel on both faces might belong to either genus. Consequently we have had to rely on isolated premolars for identification of *Thomomys*.

T. umbrinus with more than 200 described subspecies ranges over much of Mexico and western United States. It has been taken on the Edwards Plateau and the type locality of the isolated race, *T. u. confinalis,* is less than 15 miles from Schulze Cave. Other races occur in the Trans-Pecos region, to the west, and in the Mountains of New Mexico. Although *Thomomys* is one of the less common forms in Schulze Cave, a jaw from layer B and specimens from layers C1 and C2 are referable to this genus. Apparently *Thomomys* was resident in the vicinity throughout the period of deposition.

Geomys has been reported in numerous Pleistocene deposits in Texas but the only previous record of *Thomomys* that we can find is Dalquest (1965) from Hardeman County in northern Texas. He referred the specimens (2 upper premolars) to *T. talpoides,* the species now is found in north-central New Mexico. *T. umbrinus* also is found in northern New Mexico, and the teeth might be referable to that species as readily as to *talpoides.*

In trying to find characters to separate the upper premolars of *umbrinus* from those of *talpoides* we relied on specimens of both species from northern New Mexico and southern Colorado, principally of *T. t. fossor* and *T. u. pervagus* and *T. u. cultellus.* We discovered no reliable characters. A relatively large number of specimens had extremely angular, elongated premolars. Even when the apparently aberrant individuals were eliminated, the amount of variation in the premolars seemed excessive.

Geomys bursarius — Plains Pocket Gopher

Layer C1: 4 fragmentary skulls, 44 jaws with teeth, hundreds of isolated teeth (7273). Layer C2: 5 fragmentary skulls, 5 lower jaws with teeth, 79 isolated premolars, numerous other isolated teeth (7347).

This material is distinct from specimens of *Thomomys* (see preceding account), but not of good enough quality to determine whether it might also include *G. personatus,* the Texas pocket gopher.

Found in the valley of the Rio Grande in Val Verde and Kinney counties, to the south and west of the Edwards Plateau, *personatus* lives in deep, sandy soil (Davis, 1960) and, in spite of the presence of some sand-loving species at Schulze Cave in the late Pleistocene, we doubt that it would even then have found the Edwards Plateau suitable habitat.

G. bursarius has been taken on the Edwards Plateau but not near Edwards County. The type locality of *G. b. texensis* in Mason County, 60 miles northeast of Schulze Cave, seems to mark the southwestern limit of range of this pocket gopher in Texas. *G. bursarius* must have ranged over most of the Edwards Plateau, at least in the late Pleistocene and early Recent. *G. b. texensis* was described as one of the smallest races of *Geomys* then (1895) known. The skulls and jaws from Schulze Cave are of medium size, and represent a form racially distinct from *texensis*.

Cratogeomys castanops, the yellow-faced pocket gopher, occurs just west of the Edwards Plateau and has been taken in Val Verde County 60 miles west of Schulze Cave. We expected some form of *Cratogeomys* on the Edwards Plateau in the later Pleistocene and Recent, for *C. c. lacrimalis* today occupies habitat similar to that of the Edwards Plateau in the Davis Mountains of Trans-Pecos Texas.

Upper jaws of *Cratogeomys* are easily separated from those of *Geomys* (and *Thomomys*) by the absence of enamel on the posterior faces of the molars. Lower jaws of *Cratogeomys* have the angular process, just labial to the articular process, constricted at the base and spatulate-shaped. In *Geomys* this process is simple, not constricted at the base, and tapering to a blunt point. Upper incisors of *Cratogeomys* have a single groove, those of *Geomys* have two. All the skulls and jaws from Schulze Cave, including Pleistocene and Recent specimens and unlisted lower jaws without teeth were examined, but none were referable to *Cratogeomys*.

The general geographic range of *G. bursarius* is from eastern Texas northward over the Great Plains of southern Canada. The species has a great range of tolerance to varied ecological conditions but requires open land free of forest or dense brush cover, and moderately deep, soft soil. It does not live on firm, clay soils but does occur on stony soil. No habitat suitable for gophers exists today within a half-mile of Schulze Cave. When the climate was more humid during the late Pleistocene and early Recent, deeper soils must have been closer to the cave mouth.

Texas Pleistocene deposits have produced many records of *G.*

bursarius, and the species' range was more extensive on the Edwards Plateau in the Pleistocene than at present (Lundelius, 1967).

Perognathus cf. *P. merriami* — MERRIAM'S POCKET MOUSE

Layer C1: 56 skulls and skull fragments with teeth, 379 lower jaws with teeth (7274). Layer C2: 11 skulls, 124 jaws with teeth (7348).

Remains of pocket mice are the most numerous fossils in the Pleistocene layers of Schulze Cave. More than 1,000 skulls and jaws were recovered from the two layers combined, about equally divided between two species. We suspect that these numbers reflect food preference of the barn owls as well as availability because of abundance.

Three species of small, silky pocket mice occur in Texas and must be considered in identifying the cave specimens: *Perognathus flavus*, *P. flavescens*, and *P. merriami*. The skull of *flavus* is distinct from that of the other two species, especially in the breadth of the interparietal. A good proportion of the listed skulls have this bone intact, and none are like *flavus*. Lower jaws and teeth of the three forms are virtually identical and we cannot separate modern specimens on the basis of these elements. The several hundred lower jaws are not specifically identifiable. Because no skulls of *flavus* are recognized in the collection from Schulze Cave we are forced to regard this species as being absent from the fauna.

We cannot separate the fragmentary skulls or lower jaws from Schulze Cave from either *flavescens* or *merriami*. The Edwards Plateau is within the present-day range of *merriami*. *P. flavescens* occurs on the High Plains, 200 miles north. While possibly *flavescens* once ranged onto the Edwards Plateau we have no evidence that it did so. At least some, and probably all, of the small *Perognathus* from the cave are *merriami*. The species has a broad range of tolerance to environmental conditions, is much less restricted to areas of sand or sandy soil than most pocket mice and, on ecological grounds, we suspect it would be more apt to live near the cave than either *flavus* or *flavescens*. We refer the entire series of specimens from the cave to *merriami*, with the reservation that some specimens might actually be *flavus* or *flavescens*, but doubt that their presence will ever be proved.

The present range of *merriami* extends from southern coastal Tamaulipas northward over central and western Texas to the Panhandle and adjacent parts of New Mexico and Mexico.

Frank (1964) cites several records of *merriami* from Pleistocene and early Recent cave deposits in Texas. In view of our own difficulty in separating *merriami* jaws and teeth from those of *flavus* and *flavescens,* we suspect that the identifications are founded primarily on geographic probability.

Perognathus hispidus — HISPID POCKET MOUSE

Layer C1: 130 skulls or skull fragments with teeth, 332 jaws (7275). Layer C2: 30 skulls, 84 jaws (7349).

The materials appear to be identical to skulls and jaws of the modern hispid pocket mouse. The series was carefully examined to see if any might be medium-sized species, such as *P. nelsoni* or *P. intermedius,* but these forms are absent. Several species of pocket mice the size of *P. nelsoni* occupy the Trans-Pecos region, west of the Edwards Plateau.

We collected pellets regurgitated by barn owls at a number of places in central and western Texas. Almost invariably they contained skulls of pocket mice, especially of *hispidus,* in greater proportion than our trapping records indicated in the regional fauna. We suspect that pocket mice are especially sought by barn owls or are especially susceptible to barn owl hunting methods. Consequently their number in the fossil collection from Schulze Cave may not represent actual abundance though certainly they were common near the cave. Their abundance increased in the younger, upper layers of the Pleistocene deposit.

P. hispidus ranges from central Mexico northward over the Great Plains to North Dakota. It is found over nearly all of Texas. The species has a relatively broad ecological tolerance. It requires grassland or openings in brushland and avoids thickets and forest. It may live in rather dense cover of weeds or bushes if some openings are close. It also lives, often in large numbers, in open, shortgrass plains or sandy, weed-grown fields.

The distinctively large size of jaws and teeth make fossils of the hispid pocket mouse easily recognized. Records from the Pleistocene of Texas are numerous. Patton (1963) found it at Miller's Cave on the Edwards Plateau.

Dipodomys ordii — ORD'S KANGAROO RAT

Layer C1: 5 jaws (7276). Layer C2: 2 jaws and some isolated teeth (7350).

The jaws and teeth cannot be distinguished from those of modern *Dipodomys ordii.* Jaws and teeth are distinctly larger than those of specimens of *D. merriami*. From *D. elator* the jaws from the cave differ in smaller size, rounder cheek teeth, and more extensive enamel on premolars and molars.

Ord's kangaroo rat ranges from southern Mexico northward through the Great Plains and western United States to southern Canada. It is found in the Panhandle and much of western and southern Texas. In Texas, and especially in the eastern part of its range, it is rather strictly confined to sand or very sandy soil. It does not occur now on the Edwards Plateau, but does occur to the west and south. The absence of kangaroo rats on the Edwards Plateau probably reflects the absence of sand. Their scarcity in the Schulze Cave Local Fauna probably means sandy areas were scarce nearby, but without some sand dunes or sandy flats within a few miles, the fauna would have contained no *Dipodomys* at all.

Records of *Dipodomys* from the Pleistocene and early Recent are surprisingly rare. Dalquest (1965) lists *ordii* from Hardeman County, Texas. Frank (1964) does not cite a single record of *Dipodomys* from early Recent or Pleistocene cave deposits of Texas. Harris and Findley (1964) record *ordii, merriami,* and *spectabilis* from Bernalillo County, New Mexico, in a cave deposit of Pleistocene age.

Oryzomy palustris — MARSH RICE RAT

Layer C1: 1 maxillary with complete cheek-tooth dentition (7277).

Of the hundreds of cricetine jaws collected in Schulze Cave, a single jaw belongs to the rice rat. The specimen is beautifully preserved and specific identification is certain. Compared with skulls of rice rats from Aransas County, on the Texas coast, the fossil maxillary is somewhat larger, but the teeth are not sufficiently worn to disclose the enamel pattern. Probably the jaw should be referred to *O. p. fossilis,* known from Pleistocene deposits from northern Texas (Dalquest, 1962a, 1965) to Kansas (Hibbard, 1955), but we hesitate so to refer it on the basis of a single specimen and a single character, size.

O. palustris ranges today from the coast of southern Texas northward through eastern Texas and Oklahoma and eastward to the Atlantic. If the races of *O. couesi* are included as subspecies of *palustris,* much of Mexico and Central America must be added. The marsh rice rat prefers tall, lush meadow vegetation, low, humid thickets, and presence of water. It can and does live in dry habitat if the cover is suitably dense, but its preference for damp situations is marked. The absence of aquatic mammals in the Schulze Cave Local Fauna suggests that no water was near enough for barn owls to reach during their normal hunting activities. The abundance of microtine rodents shows fairly dense grassy cover nearby, which was probably too short and open to support a rice rat population The single specimen does prove that rice rats occured on the Edwards Plateau in the late Pleistocene. No rice rats live now, so far as we can determine, nearer than 200 miles southeast of Schulze Cave.

Frank (1964) cites a record of *Oryzomys* sp. from a cave fauna of Pleistocene age in Uvalde County, not far from Schulze Cave. This, the record from northern Texas mentioned above, and a record from near Houston, within the present range of the species (Slaughter, 1965) seem to be the only reports of *Oryzomys* from the Pleistocene of Texas.

Reithrodontomys montanus — PLAINS HARVEST MOUSE

Layer C1: 83 jaws (7278). Layer C2: 52 jaws (7351).

Jaws of *Reithrodontomys montanus* may be separated from jaws of *R. megalotis* by their small size and small teeth. From *R. fulvescens, montanus* differs in small size and a C- rather than S-pattern on the third molar (Hooper, 1952).

The tooth patterns of *R. montanus* and *megalotis* are similar. As a check on the validity of size as a character separating *montanus* from *R. fulvescens,* 60 specimens from layer C1, containing the last molar, were identified by size alone as *montanus*. Others were identified as "*fulcescens* or *megalotis.*" The third molars of the 60 jaws called *montanus* were then studied, and only one had the S-pattern of *fulvescens*. As *R. megalotis* is at least as large as *fulvescens,* we feel confident that the 59 remaining specimens are all *montanus.*

The plains harvest mouse ranges from the central Mexican Plateau northward over the Great Plains to South Dakota. It is found in all but coastal and eastern Texas. Preferred habitat is short, dense grass, but it lives in a variety of situations ranging from open desert to open brush and tall grass. It avoids wet or marshy places, woodlands and forests. *R. montanus* has been taken on the Edwards Plateau but we know of no specimens collected in Edwards County.

Pleistocene cave deposits have yielded several records of *R. montanus* (Frank, 1964), and some of the harvest mouse specimens identified only to genus are probably *montanus.*

Reithrodontomys megalotis — Western Harvest Mouse

Layer C1: 1 jaw (7279). Layer C2: 6 jaws (7352).

The western harvest mouse ranges from southern Mexico northward through western United States and the Great Plains to southern Canada. Throughout this large area it occupies varied ecological habitats from desert to tropics and subartic alpine meadows. Although it avoids forest it occupies brushland and openings in forest, and even lives in open woodlands. It is therefore difficult to account for the curious hiatus in its geographic range, a hiatus that includes a continuous region of varied and largely suitable habitat in northeastern Mexico, most of Texas, Oklahoma, Arkansas, and Louisiana.

In Texas *megalotis* occurs in the Trans-Pecos region of western Texas and the High Plains, including the western part of the Panhandle. Its range in Texas has not been mapped in detail, but appears to have been reduced in recent years by intensive agriculture. The Edwards Plateau is well within the hiatus mentioned. The nearest records of occurrence are more than 100 miles to the west, but we suspect that *megalotis* will eventually be found closer, but west of, not on, the Edwards Plateau.

R. megalotis has been reported from a number of Pleistocene deposits in Texas, east of the present border of its range. Patton (1963) found this the only fossil harvest mouse in Miller's Cave in Llano County on the Edwards Plateau.

Reithrodontomys fulvescens — Fulvous Harvest Mouse

Layer C1: 13 jaws (7280). Layer C2: 1 skull, 25 jaws (7353). An additional 137 jaws, 35 from layer C1 (7281) and 102 from layer C2 (7354), are so large that they are probably assignable to *R. fulvescens*, but some may be *R. megalotis*. They have been catalogued as *R.* cf. *R. fulvescens*.

Lower jaws of *fulvescens* and *megalotis* can be separated from jaws of *montanus* by large size, but we could find no reliable character to separate the two species from each other unless the third molar was present. If present and not too greatly worn, the posterior fold of M3 extends lingually and posteriorly to form, with the anterior folds of the tooth, an "S" pattern (see Hooper, 1952). Other differences between the tooth patterns of the two species have been reported, but we found these unreliable because of individual variation and variation from wear. Only the pattern of the M3 can be depended on.

Unfortunately the M3 in these two species is only loosely attached in the alveolus. In 2 out of 3 of the large harvest mice from Schulze Cave, the M3 is missing in contrast to only 1 out of 3 lower jaws of the small *montanus*. The proportions are essentially the same in both layers C1 and C2. A number of jaws have teeth too greatly worn to determine the pattern of M3. These, together with lower jaws missing M3 and upper jaws, constitute the *R.* cf. *R. fulvescens* category.

R. fulvescens is a southern form, ranging over most of Mexico and northward over much of Texas, Oklahoma, Arkansas, and Louisiana. In Texas the species is found from the Trans-Pecos region eastward through the Edwards Plateau (Kerr County, Davis, 1960) to eastern Texas. The Texas Pleistocene contains few records of *fulvescens*. Dalquest (1965) found *megalotis, montanus,* and *fulvescens* together in a Pleistocene deposit in Foard County in northern Texas, as we found the three species in Schulze Cave. All three species occur today in the Trans-Pecos region, but whether or not in the same habitat we do not know.

Peromyscus maniculatus — Deer Mouse

Layer C1: 79 jaws (7282). Layer C2: 145 jaws (7355).

The hundreds of *Peromyscus* jaws in the Pleistocene deposits from Schulze Cave present problems in identification that have not been resolved to our complete satisfaction. The range of individual variation in the dental characteristics and also in the size of the jaws and teeth of the many Recent species is surprisingly large (see Hooper, 1957). Species that exhibit considerable difference in gross size of body and skull may have lower jaws and teeth that overlap broadly in measurements. Fortunately some groups and species have dental characters that, in combination, are unique among the several forms of Recent *Peromyscus* that, on geographic grounds, may once have lived on the Edwards Plateau.

For example the geographic range of *P. eremicus* approaches Schulze Cave on the south and west. None of the fossil jaws have the simple enamel pattern of M1 and M2 and small M3 characteristic of *eremicus* and other mice of the subgenus *Haplomylomys*. Absence of *eremicus* from Schulze Cave is in agreement with the ecological data also, for it is a species of the arid deserts. None of the species of pocket mice and kangaroo rats, almost everywhere found associated with *eremicus*, are present in the Schulze Cave fossils.

The reverse situation is presented by *P. gossypinus* (LeConte), now found no closer to Schulze Cave than the forests of far eastern

Texas. The presence of the chipmunk, short-tailed shrew, rice rat, and similar eastern species suggests that ecological conditions at Schulze Cave might once have been suitable for *gossypinus*. *P. gossypinus* averages larger in tooth and jaw measurements than *maniculatus* or *leucopus*, and the extreme measurements are greater, but the measurements overlap broadly. The largest *leucopus* are larger than 80% of the *gossypinus* examined. We could find no qualitative characters to separate the two species.

Over most of southeastern United States *gossypinus* is smypatric with *P. nuttalli*, the golden mouse. No jaws from Schulze Cave have the distinctive dental characters of *nuttalli*. Because the largest *leucopus*-type jaws from Schulze Cave are smaller than the largest *gossypinus* jaws from eastern Texas, and because we found no *nuttalli* in the cave collection, we feel that *gossypinus* can be eliminated from the Schulze Cave faunal list.

Three *Peromyscus* species, *leucopus*, *pectoralis*, and *boylii*, live on the Edwards Plateau today and a fourth, *maniculatus*, occurs in the Trans-Pecos region to the west and also less than 100 miles to the east. At present *pectoralis* seems to be the most common species on the plateau.

P. leucopus and *maniculatus* are members of the *maniculatus* group, while *pectoralis* and *boylii* belong to the *boylii* group. Mice of the two groups differ in details of size, body proportions, and pelage, but differences in jaws and teeth are slight and overlap broadly. *P. boylii* is the largest, with large, complicated teeth (more lophs and styles). *P. pectoralis* is smaller with smaller, less complicated cheek teeth. *P. leucopus* is smaller yet, with jaws and teeth averaging smaller and distinctly less complicated. *P. maniculatus* is smallest of all, with teeth and jaws averaging smallest in size but lophs and styles as in *leucopus*. While jaws and teeth of *leucopus*, for example, can be separated from those of *boylii* with almost 100% confidence, neither can be so separated from the intermediate *pectoralis*. In most characters, and especially in size, each species is broadly overlapped by at least one other species.

We discovered one character that separates lower jaws of *pectoralis* and *boylii* from those of *maniculatue* and *leucopus* in nearly all instances. In *leucopus* and *maniculatus* the posterior tip of the root of the incisor bends labially, and the thin bone of the labial wall of the mandible forms a bulged capsule about it (Figure 2B). The prominent capsule is distinctly rounded laterally and extends above the level of the bony ridge that extends to the articular

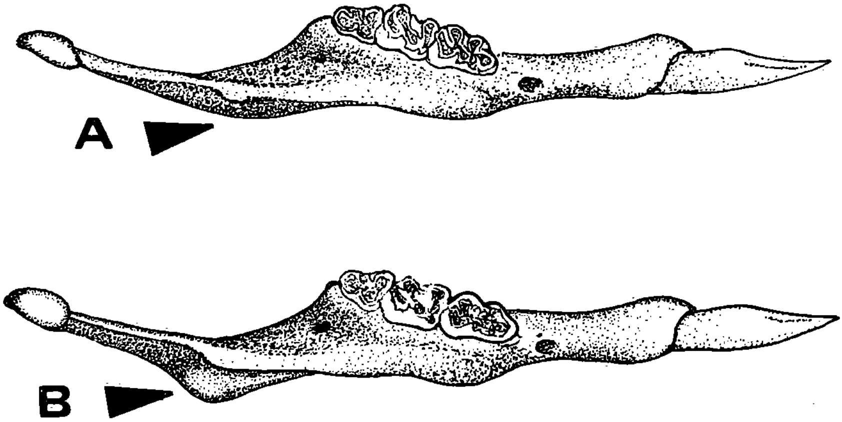

Figure 2. Lower jaws of A. – *Peromyscus pectoralis* and B. – *Peromyscus leucopus* showing bulged capsule about root of incisor.

condyle. This bulged capsule is not the result of age, for it is fully developed in all mature mice, nor is it due to size, for it is equally developed in several species of *Reithrodontomys* as well as in the much larger *Oryzomys palustris.*

Lower jaws of *pectoralis* and *boylii* have the incisor root tip bent labially little or not at all. As seen from above, there may be no trace of a bulge or perhaps only a slight thickening of the bony ridge (Figure 2A). Sometimes the ridge may be elevated to form a long-based triangle with the apex over the tip of the incisor root. Rarely there is a poorly-developed bulged capsule. Of the *boylii* specimens examined 8% had a low bulge, smaller than all but the smallest capsules noted in *leucopus.* None of 50 *pectoralis* specimens had more than a trace of a bulged capsule.

The thin bone surrounding the base of the incisor root is often broken away in the fossil jaws from Schulze Cave, exposing the incisor root. Such breakage is much more common in the jaws of the *leucopus* type, with the distinct capsule. Even when broken, the jaws could be allocated to type by the amount of labial curvature of the incisor root. When the cave jaws were separated on the basis of the incisor capsule, jaws with very small capsules or none at all were invariably larger and had more complicated teeth than jaws with well-developed capsules.

Lower jaws so damaged that the capsule could not be studied and upper jaws were identified as to *leucopus*-type or *boylii*-type on the basis of size and complexity of teeth. Some error is doubtless present in the allocation of the upper jaws and damaged lower jaws.

With the *boylii*-type jaws removed, the fossil *Peromyscus* collection remained heterogeneous. No qualitative character could be found to separate the jaws into two or more groups, but tooth measurements when plotted formed a bimodal curve. Finding measurements suitable for the fossil jaws was difficult. Fossil incisors are often damaged and articular and coronoid processes missing or broken. In cheek teeth the molars, especially the M3, are often missing and alveoli damaged. We therefore adopted the crown length of M1-M2 from the posterior edge of the tooth enamel of M2 (not of occlusial pattern) to the anterior edge of the enamel of the crown of M1, as our criterion. This measurement can be taken accurately in teeth of even relatively young mice, so common in fossil collections, except where the M3 is not completely erupted. In these juvenile mice the anterior molars seem not yet fitted closely together, and measurements are excessive. In animals with the enamel pattern worn away and crown worn down past its greatest dimension, abnormally small measurements result. Such very old dentitions cannot be identified. When M2 is lost but M1 and M3 are present, we measure from the anterior edge of M3. If only M1 is present, the posterior edge of M2 is estimated to lie just above the anterior root of M3. If M1 is missing, the anterior edge of M1 is estimated to lie just anterior to the anterior alveolus of M1. Jaws lacking both M1 and M2 were not used.

Lower jaws of 50 specimens of *P. l. texanus* trapped in central and north-central Texas were measured as described above with an accurately calibrated occular micrometer under a 10-power microscope. Measurements ranged from 2.7 to 2.9 mm, with only two specimens smaller than 2.7 mm. Measurements were essentially similar for smaller series of *leucopus* from elsewhere in the United States and Mexico.

In the fossil jaws from Schulze Cave, layer C1, approximately one-third had the M1-M2 distance 2.7 mm or less. Some measured only 2.5 mm. In layer C2, half the lower jaws had the M1-M2 distance 2.7 mm or less, again often as small as 2.5 mm. Clearly these small jaws are not *leucopus*.

P. maniculatus averages smaller and lighter in build than *leucopus*. *P. m. blandus* is found in the Trans-Pecos region west of the Edwards Plateau. *P. m. pallescens* occurs in the lower areas just east of the Edwards Plateau. *P. m. osgoodi* and *P. m. rufinus* occur in the mountains of northern New Mexico in association with several other members of the Schulze Cave local fauna. The lower M1-M2 distance was measured on good series of all four of these races. In *blandus, rufinus,* and *osgoodi* the distance was 2.7 mm or more, as in *leucopus.* We strongly doubt that teeth or jaws of these races can be distinguished from those of *P. l. texanus. P. m. pallescens,* as known to us mostly from specimens from north-central Texas, had teeth smaller than the other races, M1-M2 distance 2.5 to 2.7 mm. This range is almost identical to that of the smaller Schulze Cave *Peromyscus.* We have therefore referred to *P. maniculatus* cf. *pallescens* all the lower jaws from Schulze Cave with the M1-M2 distance 2.7 mm or less. A few of the smallest *leucopus* may be included. Upper jaws, damaged lower jaws and lower jaws with greatly worn teeth are referred to *maniculatus* or *leucopus* on the basis of size, with, we estimate, 75% accuracy.

Peromyscus leucopus — WHITE-FOOTED MOUSE

Layer C1: 168 jaws (7283). Layer C2: 1 skull, 153 jaws (7356).

As described in the preceding account, we assign to this species all *Peromyscus* lower jaws with the M1-M2 distance more than 2.7 mm. and with well-developed capsular bulges about the bases of the incisor roots. If specimens of a race of *maniculatus* other than *pallescens* were present in the collection, they would be included with the specimens called *leucopus.* As *pallescens* is present in both C1 and C2 layers, though relatively less common in the upper layer, we doubt the presence of another race. Rarely are two subspecies of *maniculatus* sympatric. Upper jaws and damaged lower jaws are assigned to *leucopus* on the basis of size and simplicity of molar teeth.

The geographic range of *leucopus* extends from southern Mexico to Canada, principally east of the Rocky Mountains. It is found over most of Texas, including the Edwards Plateau, and records from Texas Pleistocene deposits are numerous.

Peromyscus pectoralis — WHITE-ANKLED MOUSE

Layer C1: 170 jaws (7284). Layer C2: 22 jaws (7357).

Jaws and cheek teeth of the white-ankled mouse average slightly larger than those of *leucopus,* but measurements overlap broadly. The largest *pectoralis* are larger than the largest *leucopus.* Jaws and teeth of *pectoralis* are the size of some *gossypinus,* perhaps a trifle larger. The molars of *pectoralis* are more complicated on the average than those of *leucopus.* Fortunately the nature of the capsule enclosing the base of the incisor root separates the lower jaws of *pectoralis* from those of *leucopus*. Size and complexity of the molars, especially the development of the mesostyle and mesoloph, aid in separating upper jaws of *pectoralis* from those of *leucopus*.

The incisor-base capsule is underveloped or very poorly developed in *pectoralis* and *boylii*. *P. boylii* has larger jaws and larger teeth than *pectoralis*. Molars, especially M^2, are more complicated in *boylii*. Closed enamel islands commonly occur in M^1 and M^2 of *boylii*, and sometimes even in M_1 or M_2. Very rarely a closed island occurs in M^1 of *pectoralis;* never in M_1 or M_2. The combination of large size of jaw and teeth and complicated teeth of *boylii* permits separation of the two species. On these characters we were able to separate 90% of the Recent specimens from Texas that we studied.

P. pectoralis ranges from central Texas, southern Arizona and southern New Mexico southward to southern Mexico. In Texas the species occurs in the Trans-Pecos region and in the hilly, limestone regions from the Edwards Plateau northward to the central part of the state. Its preferred habitat is rocky hillsides, especially limestone, with some cover of tall brush or trees. It avoids level areas, low cover, and ground free of loose rock. On rocky hillsides the cover may vary from juniper thickets, tall, mixed brush or scrub oak, persimmon and black walnut, or even dense tropical forest. Suitable habitat probably regulates its distribution in Texas. However, *pectoralis* is a southern, primarily Mexican, species. Factors other than rocky hillsides may prevent it from extending its range farther northward.

Although the general range of *pectoralis* includes much of the Mexican Plateau and Trans-Pecos Texas, the white-ankled mouse does not live in arid desert. It occupies the many isolated desert mountain ranges where habitat is suitable, and is not found in intervening country. This distribution suggests a much broader, more inclusive, geographic range in a past climatic cycle.

At present *pectoralis* seems to be the commonest mouse on the Edwards Plateau. We can find no previous record from the Pleistocene of Texas. Crindlebaugh (1962) lists this form from Uvalde County, just south of Edwards County, from a Recent deposit estimated to be ca. 1,000 years old. Patton (1963) did not record *pectoralis* from Miller's Cave in Llano County, but did list *leucopus* and mentioned that seven jaws were "distinctly larger than Recent specimens of either *P. maniculatus* or *P. pectoralis*." As *pectoralis* is slightly larger than *leucopus* in the large series we studied, we wonder whether some of the specimens Patton (1963) identified as *leucopus* might not be *pectoralis*.

Peromyscus boylii — BRUSH MOUSE

Layer C1: 85 jaws (7285). Layer C2: 43 jaws (7358).

Our reasons for assigning lower jaws to *boylii* are given in the discussions of *maniculatus* and *pectoralis*. The upper molars of *boylii* tend to be especially large and to have complex accessory lophs and styles. In many teeth from Texas the M1 and M2 in the proper stage of wear show closed, isolated enamel islands. Such islands may occur in the M3 of other *Peromyscus* species, and especially in *pectoralis*, but not in the upper M1 and M2. Similar islands occur regularly in the upper and often in the lower molars of *Oryzomys palustris*. The enamel islands of *boylii* are less common than in the rice rat, are shallower, and do not persist as long. Jaws and teeth of *boylii* are distinctly smaller than those of *O. palustris*, and in addition lack the enlarged capsular process present in *palustris*.

P. boylii ranges from Honduras and El Salvador northward to Utah, Wyoming, and Nebraska. It is found in rocky and brush-covered areas of western and north-central Texas. Its habitat preference is similar to but broader than that of *pectoralis*. The ecological relationships of *boylii* to *pectoralis* have not been studied in detail. The two species are sympatric but may be ecologically separated.

Curiously enough, we find no identifications of *boylii* from Pleistocene deposits in Texas. Jakway (1958) lists skulls and jaws of *boylii* from San Josecito Cave, Nuevo Leon, Mexico, but we know of no closer records.

Baiomys taylori — NORTHERN PYGMY MOUSE

Layer C1: 18 jaws (7286). Layer C2: 3 jaws (7359).

Our specimens are very similar to specimens of *B. taylori* from Aransas County on the Texas coast and to specimens from Tamaulipas, Mexico. Robert Packard of Texas Technological College, who has studied fossil and Recent pygmy mice, examined our material and confirmed the identification.

The northern pygmy mouse ranges from southern Mexico northward to southeastern Arizona and southern and eastern Texas. Its range includes the Edwards Plateau, but it is rare there at present. Its preferred habitat is dense, grassy or weedy cover. Height of the grassy cover seems to be immaterial if it is dense enough to keep their runways shaded and the surface of the ground damp and humid. Pygmy mice avoid trees but occur in bushes in thickets if the ground cover is suitably dense. Little habitat of this type presently occurs on the Edwards Plateau.

Packard (1960) speculates that the present northern limit of range of *Baiomys* may have resulted from a relatively late invasion, and that the armadillo and cotton rat also invaded Texas at a similar time. The evidence from Schulze Cave suggests this in part, for the pygmy mouse is rare (3 jaws) in layer C2, and more common in the younger layer C1. The armadillo, however, reached Texas much later, in the last century or so, and the cotton rat earlier.

We know of no certainly-dated late Pleistocene records of *Baiomys* from Texas. Frank (1964) cites several records (Val Verde, Kinney, Comal, and Travis counties) from southern Texas caves, some of which were carbon dated at 1,000 to 2,000 years BP. Others may be older, but we doubt that any are of Pleistocene age.

Onychomys leucogaster — NORTHERN GRASSHOPPER MOUSE

Layer C1: 129 jaws (7287). Layer C2: 42 jaws (7360).

Onychomys molars are distinctive and cannot be easily confused with those of other cricetines. *O. torridus*, a species of the desert areas of the Trans-Pecos region, has distinctly smaller jaws and teeth. The largest *torridus* approach the smallest *leucogaster* in size, with little or no overlap in measurements. We compared the jaws from Schulze Cave with both species, and none are referable to *torridus*.

O. leucogaster ranges from northern Mexico northward through the Great Plains and western states to southern Canada. It prefers arid regions, including hot, sandy deserts, mesquite or sage plains, and arid grasslands. In Texas it is now rather strictly confined to areas of sand or quite sandy soil. The eastern limits of its range are usually in the sandy terraces of eastward-draining rivers.

Little habitat for *Onychomys* exists in the vicinity of Schulze Cave today, but the presence of *Spermophilus spilosoma, Dipodomys ordii,* and similar sand-loving forms in the Schulze Cave Local Fauna shows that sandy flats were present in the late Pleistocene. We know of no specimens of *Onychomys* trapped on the Edwards Plateau, but Hollister (1914) records is from San Angelo, not far away.

Many *O. leucogaster* are on record from Pleistocene and early Recent deposits of Texas. The species seems to have been resident in the state throughout the late Pleistocene to the present. The discovery of three times as many *Onychomys* jaws in layer C1 as in layer C2 suggests the species became more common near the cave in the latest Pleistocene.

Sigmodon hispidus — Hispid Cotton Rat

Layer C1: 3 skulls, 729 jaws (7288). Layer C2: 176 jaws (7361).

Because the geographic ranges of S. *ochrognathus* and S. *minimus* are far removed from Schulze Cave we have not compared our material with those species. We cannot distinguish the Schulze Cave jaws and teeth from those of the hispid cotton rat.

The great number of jaws in the deposit shows that the cotton rat was abundant in the vicinity of the cave, but it also reflects the hunting habits of the barn owl. These owls either prefer to prey on cotton rats or they are especially successful in capturing them. Over much of Texas cotton rats are the principal food of barn owls today.

The difference in numbers of cotton rats in the two layers suggests the species became more abundant in the later and latest Pleistocene.

S. *hispidus* ranges from Panama northward through Central America to Kansas and Missouri, and nearly from coast to coast. Much of its northern range has been occupied only in the past century. Cotton rats have great ranges of tolerance to environment. They occupy grassland or weedy-areas from semideserts to lush, wet meadows.

Many *hispidus* have been recorded from late Pleistocene and Recent deposits. The earliest record is the lower Shuler Local Fauna in Dallas and Denton counties (ca. 37,000 years BP, Slaughter et, al., 1962). The species is absent from the earlier Easley Ranch Local Fauna (Dalquest, 1962), and other species are known from early Pleistocene faunas. S. *hispidus* seems to have been resident in Texas since the earliest Wisconsin.

Neotoma micropus — Southern Plains Wood Rat

Layer C1: 137 lower jaws (7289). Layer C2: 200 lower jaws (7362).

Three species of wood rats, N. *micropus*, N. *floridana*, and N. *albigula*, have been recorded from the Edwards Plateau. In addition, N. *mexicana* has been taken in the Trans-Pecos region of western Texas and N. *cinerea* occurs in the mountains of northern New Mexico, associated with other small mammals of the Schulze Cave Local Fauna. The latter two species have distinctive dental characters and are not present among the Schulze Cave fossils. Major problems involve the separation of jaws and teeth of the three local species.

Hibbard and Taylor (1960) suggest that upper jaws of *micropus* might be separated from those of *floridana* by the shape of the posterior triangle of the anterior loop of M1: the loop is rounded in *micropus* and flattened in *floridana.* This character may vary geographically and in some areas may help separate the two species, but in Texas it is useless. In 50 skulls of *N. micropus* trapped in north central Texas, approximately half had the base of the triangle rounded and the other half had it flattened. We were unable to find any character in the dental pattern of either upper or lower molars to separate *floridana* from *micropus.*

N. m. micropus averages distinctly smaller in Texas than *N. floridana attwateri.* Only the largest skulls of *micropus* are as large as the smallest skulls of *floridana* when animals of similar age are compared. Age is determined simply by toothwear, as shown by the height of the reentrant valleys on the sides of the molars. Difference in size of skulls does not extend to size of teeth. Teeth of *micropus* are as large as those of *floridana.* The length of the molar row may average slightly greater in *floridana,* but measurements overlap broadly. Breadth of molar rows, however, seems to be related to skull size, and is greater in *floridana* (8.7 – 9.2 mm) than in *micropus* (8.0 – 8.7 mm). Lower jaws of *floridana* are larger, stouter, and heavier than those of *micropus* of similar age, though the length of the lower tooth rows averages but little greater.

Separation of jaws of *Neotoma albigula* from those of *micropus* presented almost the same problem as separation of *floridana,* but in reverse. *N. albigula* is distinctly smaller than *N. micropus,* but has relatively large teeth and lower jaws. Detailed study failed to discover a single qualitative character of the dental pattern to separate the two species, nor could we find any means of separating isolated upper jaws of the two.

We did find a reliable quantitative character to separate the lower jaws of *albigula* from those of *micropus.* In *albigula* the breadth of the second fold (loph) of M1 is less than 1.94 mm, but in *micropus* it is greater than 1.94 mm. We found no overlap in Texas-taken specimens of the two species.

Palates and lower jaws of *floridana* can be identified by their large size. Lower jaws of *micropus* can be separated from those of *albigula* by the breadth of the second loph of M1. Isolated upper jaws, palates smaller than those of *floridana,* and lower jaws lacking M1 cannot be identified. More than 100 specimens of this kind have been catalogued from layer C1 (7293) and 229 from layer C2 (7364) as *Neotoma* sp.

The geographic range of *micropus* includes most of central and western Texas and adjacent parts of Mexico and the United States. The species is recorded frequently from Pleistocene deposits in Texas but, in view of our difficulties in identifying any but the most complete specimens, we doubt specific identifications based on teeth or jaw fragments.

Neotoma floridana — EASTERN WOOD RAT

Layer C1: 4 skulls, 4 lower jaws (7291). Layer C2: 1 palate, 6 lower jaws (7363).

Identification of the above material is based on size of jaws and breadth of molar rows, and is almost certainly correct. Some upper jaws of *floridana* may be included in the specifically unidentified materials, and some small lower jaws of *floridana* may have been identified as *micropus*.

N. floridana ranges from the Edwards Plateau of Texas eastward to Florida and northward to North Dakota and New England. Except on the Edwards Plateau its range seems to be allopatric with that of *micropus*. In north central Texas the two species occur within a few miles of each other, but apparently not together, and they do not intergrade. In Texas *floridana* seems to prefer rocky situations, cliffs, abandoned buildings, piles of stumps or logs, and similar habitat in broad-leafed woodlands. The western limit of its range seems to be determined by the limit of the oak belt, for it stops abruptly where the mesquite replaces the oaks. *N. micropus* perfers similar habitat in more open brushland or semidesert of central and western Texas. Habitat for both species is present on the Edwards Plateau.

So far as we know, the only record of *floridana* living on the Edwards Plateau is Rock Springs, Edwards County (Goldman, 1910), close to Schulze Cave. All other records known to us are from eastern Texas. Possibly the eastern wood rats on the Edwards Plateau are an isolated population without connection with the main range of the species.

N. floridana has been recorded from several late Pleistocene deposits in Texas. Our study of *micropus* has led us to doubt the specific identifications of some of the published records.

Neotoma albigula — WHITE-THROATED WOOD RAT

Layer C1: 18 lower jaws (7292).

Lower jaws of wood rats with the breadth of the second loph of M1 less than 1.94 mm are referred to *N. albigula* with confidence.

In the skull the breadth across the upper molar rows is 7.4 to 8.0 mm, vs. 8.0 to 8.7 mm in *micropus*. Unfortunately, few of the fossil skulls are complete enough to determine the breadth of the molar rows, and none of these few is *albigula*.

The geographic range of *N. albigula* extends from Llano on the eastern edge of the Edwards Plateau westward over most of Arizona and New Mexico, some adjacent areas, and southward over most of Mexico. Preferred habitat is dense thickets of cactus, palo verde, or other thorny shrubs, and rocky cliffs and talus in open, desertlike country. Its range is sympatric with that of *N. micropus* over much of western Texas. Although the ecological relationships of the two species remain to be worked out in detail, *albigula* seems to avoid the mesquite brushland where *micropus* is common. Where the two species occur together, *albigula* occupies cedar (*Juniperus*) thickets and *micropus* rocky situations. When *albigula* is not present, *micropus* may be abundant in cedar thickets. When *micropus* is absent, *albigula* invariably occupies available rocky situations. In dense cactus thickets on open land, only *albigula* may be expected. In mixed brushland and rocks, both species may occur in the same trapline. West of the range of *micropus, albigula* may abound in habitats that, where it exists along with *micropus*, would be occupied by *micropus* alone.

Synaptomys cooperi – SOUTHERN BOG LEMMING

Layer C1: 2 jaws, 3 isolated teeth (7294). Layer C2: 1 palate, 3 lower jaws, 4 isolated teeth (7365).

The southern bog lemming is one of the least common elements of the Schulze Cave local fauna, but some of the lower jaws are complete and very well preserved, permitting detailed study.

The relationship of the specimens of *Synaptomys* recorded from the various late Pleistocene deposits of Texas has been somewhat confused by records of the large *S. australis* from localities to the north (Kansas, Hibbard, 1955) and south (Mexico, Cushing, 1945), as well as east of Texas. Most records have been based on isolated teeth, and molars of bog lemmings are rootless and ever-growing. The molar of an extremely large, old specimen' of a small species cannot be distinguished from that of a young, small specimen of a large species.

Dalquest (1962a) referred teeth from a Pleistocene site in Foard County in northern Texas to *australis* on geographic grounds, even though they were relatively small, on the presumption that they were from young individuals. Slaughter et. al. (1962) also found small teeth in a Pleistocene deposit in Dallas and Denton counties, and referred them questionably to *australis.* As additional specimens became available from other Pleistocene sites in Texas, it became clear that the small size of the *Synaptomys* teeth was not due to age, but that the specimens were *cooperi* rather than *australis.* Apparently *australis* has not been found in Texas (Dalquest, 1965).

Patton (1963) found several fragmentary jaws of bog lemmings in Miller's Cave in Llano County on the Edwards Plateau and referred them to *cooperi,* noting that they were similar in size to specimens of the living *S. c. paludis* Hibbard and Rinker, of eastern Kansas. The more complete specimens from Schulze Cave are also clearly referable to *cooperi,* though they are indistinguishable in size from lower jaws of *S. c. gossii* from Illinois. Even the largest specimen is a bit small for *S. c. paludis.* The fossil jaws are massive and angular and seem to be from adult bog lemmings.

Hibbard (1963) noted an increase in size of fossil bog lemmings from north to south, and an increase in the posterior extension of the root of the incisor beneath M3. The incisors of the Schulze Cave fossils extend past the posterior edge of the M3 and thus fit into the cline Hibbard postulated.

The geographic range of the southern bog lemming extends from southern Kansas and northeastern Arkansas northward to southern Canada and eastward to Nova Scotia. In the southern part of its range in Kansas it is said to prefer bogs and cool, moist meadows (Cockrum, 1952: 193). No bogs existed close to Schulze Cave, and the nearest place where relatively low level ground might have supported a meadow in a cooler, more humid climate is a half-mile away, which might account for the relative scarcity of bog lemming remains in the cave.

Microtus pinetorum AND *M. ochrogaster* — WOODLAND AND PRAIRIE VOLES

Remains of voles are abundant in the upper layers of the Pleistocene deposits in Schulze Cave. In layer C1 we found 15 partial skulls, 82 jaws, 73 isolated lower M1's, and more than 100 other isolated teeth (7295). In layer C2 we took 11 partial skulls, 156 jaws, more than 200 isolated lower M1's, and many other isolated teeth (7366).

Nearly all species of American *Microtus,* except for some tropical forms and *pinetorum* and *ochrogaster,* have M_1's with five or more closed triangles anterior to the posterior loop. *M. pinetorum* and *ochrogaster* (we consider *M. ludovicianus* a race of *M. ochrogaster*) have the M_1 with three closed triangles anterior to the posterior loop, followed by two confluent triangles. We have examined carefully the more than 400 lower M1's from Schulze Cave and every tooth is of the *pinetorum-ochrogaster* type. *Mi. longicaudus, montanus, mexicanus* and *pennsylvanicus,* all forms with 5 closed triangles, occur in the mountains of New Mexico, together with other species of mammals whose bones we found in Schulze Cave, and their absence from the Schulze Cave local fauna is difficult to account for.

Patton (1963) illustrates a possible method of separating the third lower molar of *pinetorum* from that of *ochrogaster* in that "The second re-entrant angle on the M3 of *M. ochrogaster* may extend medially and abut on the posterior border of the third re-entrant angle, closing the second alternating triangle." He found that 6 *pinetorum* available to him all had open triangles, and 16 of 25 *ochrogaster* had the triangle closed. Thus teeth with the closed triangle would have to be *ochrogaster* but teeth with open triangles could be either species.

All six *pinetorum* in the Midwestern University collection captured in north central Texas and southern Oklahoma have open triangles. The character was tested in large series of mice in the University of Kansas, Museum of Natural History. Of 50 *ochrogaster* from Douglass County, Kansas, only 8 had the closed triangle. In 4 the triangle was somewhat constricted, and in 38 it was open as it is in *pinetorum.* In 50 *pinetorum* from Douglass and Greenwood counties, Kansas, the triangle was open in 43, intermediate in 5, and closed in 2. In one skull, K. U. 5020, the loop was as completely closed as it was in the most extreme development of the *ochrogaster* pattern. Although the character of the third lower molar is not completely reliable, the second reentrant angle is better developed and more often closed in *ochrogaster* than in *pinetorum.*

In the *Microtus* jaws from Schulze Cave we found the M3 was often missing, even in otherwise perfect jaws. The tooth is set just beneath the lingual surface of the mandible, and the thin covering bone is more often broken away than not. In layer C1 only 24 jaws have the M3 in place, and in layer C2 only 21. In layer C1, 3 teeth have the *ochrogaster* pattern, 1 is intermediate, and 20 are like *pinetorum.* In C2, 3 teeth have the *ochrogaster* pattern, 3 are intermediate, and 15 have the *pinetorum* pattern.

The number of teeth with the *ochrogaster* pattern is greater than one would expect in a collection of pure *pinetorum* from Kansas. Specimens of *pinetorum* available from Texas and Oklahoma, though limited in number, all have the *pinetorum* pattern, suggesting that in Texas and Oklahoma the *ochrogaster* pattern is at least no more common than it is in Kansas. We believe that the Schulze Cave collection contains at least some *M. ochrogaster.*

At present *ochrogaster* occurs no closer to Schulze Cave than Sour Lake, Hardin County, Texas (*M. o. ludovicianus*), and the species may now be extinct there. If *M. o. ludovicianus* is extinct, and no specimens seem to have been taken in many years, the next nearest locality record is in central Oklahoma. *M. ochrogaster* has been recorded from a Recent prehistoric site in Foard County, north central Texas (Dalquest, 1962b). Apparently the species ranged widely over Texas in the late Pleistocene.

On geographic grounds, one would expect *M. pinetorum* to be an element of the cave fauna. The species has been taken on the Edwards Plateau, in Kerr and Edwards counties (Bryant, 1941) close to Schulze Cave. Almost certainly some of the *Microtus* from Schulze Cave are *M. pinetorum.* Unfortunately, separation of the species, except for the specimens with the *ochrogaster* pattern, is not possible at present.

Hall and Kelson (1959) include the Edwards Plateau in the range of *pinetorum,* on the basis of Bryant's Kerr County record, and show the range continuous with the range of the pine vole in extreme eastern Texas. This is incorrect. A broad area betwen the Edwards Plateau and the woodlands of far eastern Texas is unsuitable for *pinetorum.* The Edwards Plateau should be mapped as an isolated area occupied by a relic stock of *Microtus.* No specimens of *pinetorum* seem to have been taken on the Edwards Plateau since Bryant's record. The species may now be extinct there, for more than 25 years have elasped without, so far as we can discover, anyone taking specimens.

Some authors persist in placing *pinetorum* and *ochrogaster* in separate subgenera, or even genera. The two species together, along with *M. quasiater* from Tropical Mexico, form a compact group, easily separable from other American *Microtus* on the basis of the enamel pattern of the lower M1. For this group the subgenus name *Pitymys* McMurtrie, 1831, has priority. The differences separating *Pitymys* from *Microtus* are not of more than subgeneric rank.

Separation of *pinetorum* from *ochrogaster* at more than specific rank is certainly unjustified. Detailed study of the two species during preparation of the present report shows that skulls and dentitions can be separated only on average characters. Hooper and Hart (1962) reached similar conclusions. Principal differences between the two species are in pelage and habits. Other than pelage, we could find no trenchant morphological character to use as a criterion of subgeneric difference.

Zapus princeps — WESTERN JUMPING MOUSE

Layer C1: 1 lower jaw (7296). Layer C2: jaws 9 (7369).

We found our specimens indistinguishable from specimens of *Z. princeps* from northern New Mexico. Identifying this genus presents no problems. The cave specimens do not seem referable to any of the several extinct species described.

Western jumping mice range from the Rocky Mountains of central New Mexico northward through western United States and Canada to Southern Alaska. In the southern parts of their range the mice occupy mountain ranges and high elevations. Preferred habitat is humid meadows, the edges of thickets near streams or marshes, and lush, herbaceous vegetation. Jumping mice avoid forest or woods, but occupy dense ground cover, especially where the ground is moist.

The nearest locality where *Zapus* has been recorded living at present is Cloudcroft in central New Mexico (Krutzsch, 1954). *Zapus* has not previously been reported from the Texas Pleistocene. Although the numbers are small, the evidence suggests that *Zapus* was commoner in the earlier lower layer and became rare later. The single jaw from layer C1 probably came from the lower part of the layer.

Canis latrans — COYOTE

Layer C1: 1 skull (7297), 2 lower jaws (7298, 7299), isolated teeth (7300), and postcranial material (7303-7304). Layer C2: 1 lower jaw and maxillary of puppy with milk teeth, 1 isolated canine (7368).

The skull (Figure 3) is broken in several places but is well preserved. The two lower jaws from layer C1 lack most of the teeth and all the premolars. The skull is relatively broad, especially in the rostrum. The ascending ramus of the lower jaw is steep, and the alveolus of M3 is set relatively far back. The fossils therefore are probably referable to *C. l. harriscrooki* or are intermediate between that extinct race and the modern coyote.

Coyotes range over most of North America and, though now

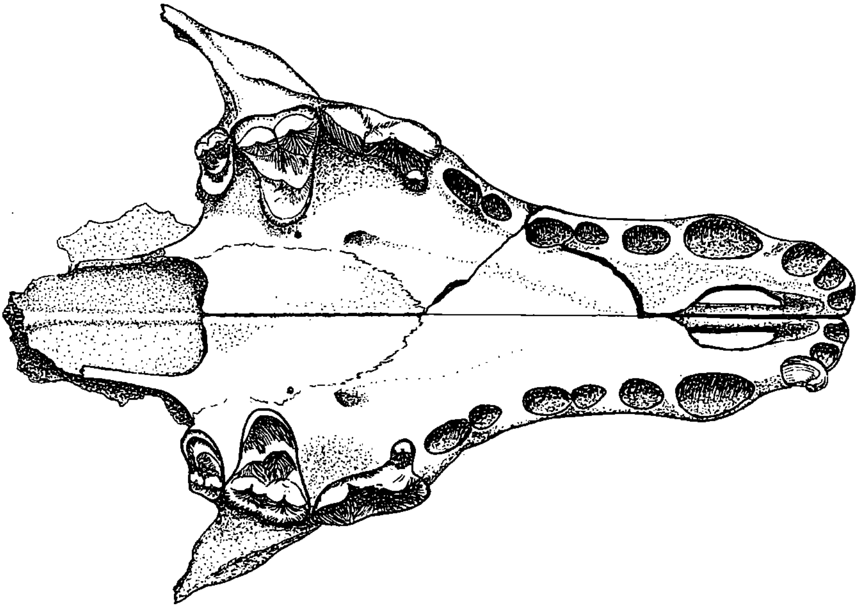

FIGURE 3. Rostrum and molars of *Canis latrans* cf. *harriscrooki* (No. MU 7297), approximately × 1.

rare from persecution by livestock owners, live on the Edwards Plateau. Fossil coyotes are known from a number of Pleistocene deposits in Texas and the southwest. The relationships of several nominal species remain to be established.

Canis cf. *C. lupus* — GRAY WOLF

Layer C2: maxillary fragment with alveolus of canine and P1-P3, median border of bone (suture) present, and part of external surface of skull (7369).

The specimen permits determination of the original breadth of the rostrum. The muzzle was much broader and probably deeper than that of a coyote or red wolf, and is approximately equal in breadth to the muzzle of a large dire wolf (*Canis dirus*) from the Rancho la Brea, California. The alveoli of the teeth, however, are smaller than those of the dire wolf and even than those of a large male gray wolf from the Northwestern Territory of Canada. The broad rostrum and relatively light teeth indicate one of the smaller subspecies of the gray wolf, or possibly a domestic dog.

Gray wolves have been extirpated in Texas, though rare individuals wander into the state from Mexico. Most records are from the Trans-Pecos region, west of the Edwards Plateau. Almost certainly the gray wolf lived on the Edwards Plateau a century or more ago.

Records of the gray wolf from the Pleistocene deposits of Texas are curiously few, and most of these are provisional. In contrast, records of coyotes are numerous, and there are quite a few records of the extinct dire wolf. Patton (1963) described a tooth from Miller's Cave that is larger than the upper M2 of the coyote and red wolf but rather small (as shown by measurements) for the gray wolf. An animal with such a tooth might compare well with one represented by the large maxillary fragment described above.

Vulpes vulpes — Red Fox

Layer C1: canine, lower P2, upper P4 (7306). Layer C2: lower milk M2, lower P2, upper M2 (7370), complete femur (7371).

Texas is not within the natural modern range of the red fox, but red foxes have been introduced for sport hunting in many sections and populations are established. The specimens listed above are indistinguishable from teeth and femurs in the Midwestern University collection of introduced specimens taken in north-central Texas. These are mapped by Hall and Kelson (1959) as *V. f. fulva.*

There has been speculation that the red foxes of the eastern United States are descended from foxes introduced from Europe in colonial times (e.g. Hall and Kelson, 1959). In view of late Pleistocene records of the red fox in cave deposits in New Mexico (Harris and Findley, 1964), Texas, Pennsylvania (Guilday et al., 1966), and elsewhere, we see no reason to doubt that the red fox was native to the eastern United States.

Slaughter (1966) reported the red fox from a Pleistocene site at Dallas, Texas, but we know of no other definite references. Some of the fossils identified only as *Vulpes* sp. may pertain to the red fox.

The gray fox, *Urocyon cinereoargentatus,* is a common resident on the Edwards Plateau today. We found no remains of this fox in the cave deposits. Most records of *Urocyon* date from the early Recent, or are from western Texas (Frank, 1964). Reexamination of all Pleistocene and early Recent fox specimens from Texas might prove profitable.

Vulpes velox — Swift Fox

Layer C2: 2 lower jaws (7373, 7374), 1 lower P4, 3 lower M1's, 1 upper P3 (7372).

Lower jaws of foxes of the genus *Vulpes* have the ventral border smoothly curved to the angular process, whereas the lower jaw of the gray fox, *Urocyon,* has a strongly developed keel anterior to the angular process. The present specimens are much too small to belong to the red fox, and the jaws are slightly larger than jaws of the kit fox, *V. marcrotis,* examined. On geographical grounds, both *velox* and *marcrotis* might occur in the Pleistocene deposits of the cave, but *macrotis* is a desert form and the Schulze Cave Local Fauna in not a desert fauna. *V. velox* is a plains species and fits well with the rest of the Schulze Cave Local Fauna.

Swift foxes have been taken no nearer Schulze Cave than Midland, Midland County, 200 miles to the northwest (Bailey, 1905). The kit fox has been reported from the mouth of Devil's River, a short distance southwestward in the low, arid valley of the Rio Grande, an eastward extension into suitable habitat well east of the species' main range. We strongly doubt the occurrence of the kit fox on the plains and woodland habitat of the Edwards Plateau.

The geographic range of the swift fox extends from Midland, Texas, northward through the Great Plains to southern Canada. If the kit fox should prove to be conspecific, the range would also extend from Val Verde County, Texas, westward through the deserts of southwestern United States and adjacent Mexico. The two nominal species are allopatric. We know of no other records of the swift fox from the Pleistocene of Texas, but some of the records of *Vulpes* sp. may pertain to the species.

Ursus americanus — Black Bear

Layer C1: 1 lower M1 (7307). Layer C2: 1 lower M1 (7375).

The molar from layer C1 is from a mature but not very old animal. It measures 19.4 by 9.5 mm, and is larger than the lower first molars of any of a series of modern black bears from the mountains of New Mexico. The molar is a trifle longer and thinner than the same tooth in a small series of black bears of near record size from Prince of Wales Island, Alaska, the largest of which measured 19.0 by 9.9 mm. The tooth is probably referable to the extinct Pleistocene race of black bear, *U. a. amplidens,* known from Saltillo Cave on the Edwards Plateau (Kurten, 1963) and from other Pleistocene cave deposits in Texas (Frank, 1964).

The molar from layer C2 is of a cub. It is unworn and roots are not completely developed. The tooth is extremely large, measuring 22.9 by 11.1 mm. In contrast the largest M1 Kurten lists for *amplidens* is 21.9 by 10.6 mm for Texas-taken specimens. The tooth is probably near maximum size for a black bear, and may have belonged to a grizzly bear.

Black bears were probably resident on the Edwards Plateau in early historic times, but have long since been extirpated. Black bear remains were present in the late Recent deposits, layer A, beneath the entrance of Schulze Cave, thought to be only a few hundred years old.

Ursus horribilis — GRIZZLY BEAR

Layer C1: numerous remains, probably of a single individual (7308), as follow: left posterior side of skull with associated cranial fragments, articulated partial fore-leg with radius, ulna, 4 metacarpals and numerous phalanges, complete femur, part of a tibia, a calcaneum, an astragalus, numerous isolated metapodials and other foot bones, a canine, several ribs and vertebrae. The bones were scattered through one limited area near the center of layer C1, which suggests that a skeleton, perhaps partially mummified, disintegrated in the entrance room of the cave, and isolated bones, or bones attached by dried skin or tendons, worked down the sloping floor to the vertical shaft and ledge. The skull must have been crushed by falling rocks in the upper chamber, for the lower jaws and muzzle were not found. We suppose these came to rest in the matrix that fell into the shaft when the ledge collapsed 4,000 years ago.

The limb bones differ in numerous details from bones of the spectacled bear, *Tremarctos,* and the short-faced bear, *Arctodus* (Kurten, 1963). The remains are of *Ursus.* Because the jaws were not found, identification to species must rest on the cranial fragments. The largest fragment includes the left side of the cranium with most of the frontal, the postorbital process, most of the parietal, the entire sagittal crest, and most of the left occipital region of the skull with almost complete occipital crest. The fragment gives few meaningful measurements but does permit direct comparison with Recent bear skulls. The specimen is from an old mature bear, as shown by closure of sutures.

The skull fragment is much larger than comparable parts of 15 black bear skulls from northern New Mexico. The largest black bear skulls on hand are 2 Boone and Crocket Club Record-size animals from Prince of Wales Island, Alaska. These animals (MU 1303, 1304, Recent Mammal Coll.) have condylobasal lengths of 297 and 299 mm. The skull fragment from the cave is distinctly larger than comparable parts of these skulls. The condylobosal

TABLE 2. MEASUREMENTS OF LIMB BONES OF FEMALE *Ursus horribilis* MU 7308

bone	greatest length	greatest proximal breadth	least medial breadth	greatest distal breadth
Radius	286	35.8	15.6	51.5
Ulna	325		17.1	35.8
olocraneon		57.5		
below olocraneon		56.0		
Metacarpal I	60.7	19.7	9.9	15.3
Metacarpal II	72.7	13.8	11.6	17.2
Metacarpal III	76.2	14.4	11.6	17.4
Metacarpal IV	79.0	15.1	11.9	18.2
Metacarpal V	79.3	18.6	11.2	20.1
Femur	366	84.8	30.0	68.4
Tibia	—	75.1	—	55.3
Metatarsal I	54.6+	—	9.7	14.9
Metatarsal II	68.6	13.3	11.4	16.8
Metatarsal III	78.5	17.8	11.8	18.9
Metatarsal IV	84.1	17.1	12.8	20.3
Metatarsal V	85.4	26.1	13.1	20.2

lengths of the 2 enormous skulls of *amplidens* listed by Kurten (1963) are 306 and 309 mm, or only a triffle larger than the Alaskan skulls. The cave skull must have been somewhat longer and considerably broader than the largest fossil or Recent black bear skulls.

The large fossil and Recent black bear skulls are of males and have strongly developed sagittal and occipital crests. The skull from Schulze Cave has very weakly developed sagittal and occipital crests and was almost certainly a female. A female bear of such large size could only be a grizzly. We have referred the specimen to *Ursus horribilis* on the expectation that all American grizzly bears will eventually be considered conspecific.

Grizzly bears in colonial times ranged over much of Mexico, western United States, and Canada. In Texas they were confined to the western part of the state. The type locality of *U. h. texensis* is in the Trans-Pecos region of western Texas. Midwestern University once had a grizzly bear cranium found in a Recent deposit near Ringgold, Montague County, Texas, and this may be the eastern limit of the range of the grizzly in Texas. The Edwards Plateau was probably once within the range of the grizzly.

In spite of its broad geographic range and known abundance in the western states in the early 1800's fossil grizzly bear remains are rare. None have been reported previously, so far as we are aware, from Pleistocene deposits in Texas.

Mustela erminea — ERMINE

Layer C1: 1 complete lower jaw (7309).

The jaw is as small as the jaw of the male least weasel, *M. nivalis*, and a small male or normal-sized female ermine. We were unable to find characters to separate the lower jaws of the male least weasel from the jaws of the female ermine. The jaw from Schulze Cave was submitted to E. R. Hall who referred it, with some hesitation, to a male of *M. e. muricus*, a small race of ermine found in the southern Rocky Mountains south to northern New Mexico.

The ermine occurs in the mountains of northern New Mexico today, but at relatively high elevations. The least weasel now ranges as far south as extreme northern Kansas. Although more distant, the locality is at a much lower elevation than record stations of the ermine in New Mexico. The Schulze Cave Local Fauna contains other elements of the southern Rocky Mountains (*Zapus, Sorex vagrans, etc.*), now restricted in New Mexico to relatively high elevations. Three factors, morphological characters, geographic proximity, and associated fauna, suggest reference of the cave specimen to *erminea*. None of the three factors alone would be conclusive but together they make reference to *erminea* highly probable.

Lundelius (1967) found *erminea* at Cave-Without-a-Name, Kendall County, Texas, the only other Texas record.

The present geographic range of the ermine extends from northern New Mexico northward over northern and arctic America and Eurasia. The site of Schulze Cave is considerably south of the present range of the ermine in North America.

Mustela frenata — LONG-TAILED WEASEL

Layer C1: 1 skull (7310).

The skull, largely complete but with the occipital region missing, was found imbedded in soft white travertine. It was sent to E. R. Hall who identified it as a female *M. f. texensis* and noted that the female of this race was hitherto unknown. Weasels are known to have occurred on the Edwards Plateau in the past, and the type specimen came from Kerr County. We suspect that the race *texensis* is now extinct. Apparently the long-tailed weasel has been extremely rare in central Texas, and common only on the Edwards Plateau. We know of no specimens taken anywhere in recent years. Many trappers we questioned remembered the weasel as common in the past on the Edwards Plateau. They caught it often in their traps, and it was a pest around their chickens, but none had seen one in many years. The weasel's disappearance seems to have made no strong impression on the trappers, and their reaction to our questioning was suprisingly uniform — a sudden recollection of the weasel, usually in regard to its theft of chickens, followed by surprise that they had seen none for so many years. We obtained no definite dates, but the species may have vanished from the Edwards Plateau about 1930.

The geographic range of *frenata* extends from northern South America to southern Canada. Where pocket gophers occur, the long-tailed weasel feeds extensively upon them, but will prey on almost any small vertebrates.

Frank (1964) cites a record of *frenata* from Travis County, Texas, but we know of no other specimens from the Pleistocene of Texas.

Taxidea taxus — Badger

Layer C2: 1 ulna (7376).

The listed specimen is our only evidence of the badger from Schulze Cave, but the badger ulna is distinctive and identification certain.

Badgers range from central Mexico northward through western and central United States well into Canada. We know of no definite records of the badger from the Edwards Plateau, and doubt its presence there in late years. Badgers perfer deep soil, preferably sandy, for their burrowing. Little such occurs on the Edwards Plateau. Perferred prey of badgers, in Texas, seems to be kangaroo rats, pocket mice, and probably ground squirrels. These seem to be rare on the Edwards Plateau now, as a result of destruction of land by overgrazing, but suitable prey was abundant in the vicinity of Schulze Cave in the late Pleistocene and early Recent.

A number of Texas Pleistocene records date back to the early Wisconsin or earlier, though none of these are from the Edwards Plateau.

Spilogale putorius — Spotted Skunk

Layer C1: 4 upper jaws, 5 lower jaws, 1 lower jaw with milk teeth (7311). Layer C2: 1 skull (7377), 1 fragmentary skull without teeth (7378), 2 upper jaws (7379, 7380), 2 lower jaws (7381, 7382).

We see no differences between the present specimens and modern *S. p. interrupta* (Rafinesque) taken in north central Texas. The one skull and several lower and upper jaws are well preserved and contain most of the teeth, permitting close comparison with Recent forms.

The Edwards Plateau is within the present range of the spotted skunk, and specimens have been taken in the eastern part of the region. Trappers in Kimble County report the species as rare.

We suspect that the relatively large number of specimens of *Spilogale* in the cave collection results from the habits of the species. It prefers cover of brush and rocks, and freely enters crevices and holes. Spotted skunks are probably too large to constitute common prey for barn owls, and the skulls and jaws from the cave are, with one exception, of fully mature or young adult animals. Great horned owls feed on spotted skunks, but these large owls rarely enter small caves.

The skull, lower jaws and part of the skeleton of a spotted skunk, largely articulated, were found in a mass of hard travertine in layer D at the bottom of the cave.

Records of *Spilogale* are numerous from late Pleistocene and early Recent deposits in Texas (Frank, 1964). Patton (1963) found the species in Miller's Cave.

Mephitis mephitis — STRIPED SKUNK

Layer C1: left side of a skull with teeth, isolated M1 (7312). Layer C2: front of a skull with complete dentition (7383), maxillary fragment, isolated teeth (7384), post-cranial material.

The above specimens are definitely referable to the striped skunk and not to the small hooded skunk, *M. macroura,* found in the Trans-Pecos region to the west.

The local race of the Edwards Plateau is *M. m. varians,* a subspecies of moderate size. The cave material, in part, represents individuals larger than the race presently occupying the area. We could not match an unusually large humerus with material at Midwestern University, but Claude Hibbard found specimens as large in the University of Michigan collections. The specimens from Schulze Cave are too limited for definite statement, but probably belonged to a different subspecies than *M. m. varians.*

Records of *M. mephitis* are plentiful in late Pleistocene and early Recent deposits in Texas (see Frank, 1964). Patton (1963) found the species in Miller's Cave.

Conepatus mesoleucus — HOG-NOSED SKUNK

Layer C1: anterior part of a lower jaw (7313). Layer C2:

anterior part of a lower jaw (7385).

The above specimens are from skunks of large size. The teeth are relatively large but can be matched with teeth of large specimens of *Mephitis*. The mandible, however, is far deeper than the mandibles of any *Mephitis* available to us, or any of 7 specimens of *C. mesoleucus* from the Edwards Plateau in the Midwestern University collection. Claude Hibbard was able to match the cave specimens with hog-nosed skunks in the University of Michigan collections, and referred the jaws to this species.

The hog-nosed skunk is a southern species, ranging from Central America northward through Mexico, Arizona, New Mexico, and Texas to southern Colorado. The species is moderately common on the Edwards Plateau, though almost always far less common than the striped skunk, *Mephitis*.

We know of no previous reports of *Conepatus* from the Pleistocene of Texas. Frank (1964) cites a record from Val Verde County, ca. 6,500 year BP, and other records from deposits of much later age. Possibly reexamination of fossils from southern Texas, previously referred to *Mephitis*, might reveal additional specimens of *Conepatus* of unquestioned Pleistocene age.

Felis onca — JAGUAR

Layer C1: tip of conjoined lower jaws (7314).

The specimen contained left I1 and I2, right I1, root of I2, complete I3 and canine. Cheek teeth are lacking. The specimen is nearly as large as the corresponding part of a large black bear, but in bears the dorsoposterior median surface of the mandible is depressed. The mandibular suture lay in a depression or groove in all of some 40 grizzly and black bear jaws examined. The large cats, in contrast (ca. 50 jaguars, African lions, mountain lions, leopards examined) have a distinct ridge along the posterior dorsal symphysal region. The cave specimen is catlike in this respect.

Unfortunately the preservation, in contrast to that of most of the cave bones, is poor. The bone is much eroded and must have been subject to considerable weathering before burial. It may have been exposed outside the cave for some time before it washed or fell into the entrance hole.

The mandible and teeth show a cat of very large size, much larger than any mountain lion, but probably too small to have belonged to the extinct *Felis atrox*. The fragment could have represented a very large jaguar, for the Pleistocene specimens of this species are relatively large (Simpson, 1941b).

The Edwards Plateau is within the historic range of the jaguar. The species occurred at Schulze Cave in the early Recent (layer B). The Texas late Pleistocene deposits have yielded several records of the jaguar.

In the late Pleistocene the jaguar ranged as far north and east as Tennessee (Simpson, 1941a). In Mexico a common food of the jaguar is the collared peccary, *Tayassu tajacu.* We found no peccary remains in Schulze Cave, but peccaries are common on the Edwards Plateau today.

Felis concolor — MOUNTAIN LION

Layer C2: 1 ulna (7386).

The bone is large, larger than the few mountain lion ulnas available from Texas, but not greatly so. Its shape and proportions are like those of the mountain lion.

The geographic range of the mountain lion includes most of North America and, in early historic times, all of Texas. The species has been extirpated on the Edwards Plateau. Davis (1960) lists an old record from Kinney County, the next county south of Edwards County. Mountain lions still persist in the Trans-Pecos region and the valley of the Rio Grande.

The Texas Pleistocene deposits contain very few mountain lion records and these are subject to question. Frank (1964) cites no records from Pleistocene or early Recent cave deposits. Records of the jaguar and giant jaguar, *Felis atrox,* are much more numerous.

Felis yagouaroundi — JAGUARUNDI

Layer C1: nearly complete lower jaw (7315), 2 astragali (7316), 1 isolated canine (questionable). Layer C2: 2 upper carnassials (7387).

All the listed bones were washed from matrix; none were noted in place in the deposit. No parts are duplicated, and so far as can be determined, all come from young adult animals with little tooth wear. The remains, scattered through the matrix at the lower level of layer C1 and the upper part of layer C2, could have come from a single animal.

The lower jaw (Figure 4) is well preserved. We compared it with specimens of bobcat, ocelot, and jaguarundi. Many features separate the jaguarundi from the other species, especially size and breadth of teeth, depth of jaw and location of foramina. In all these features

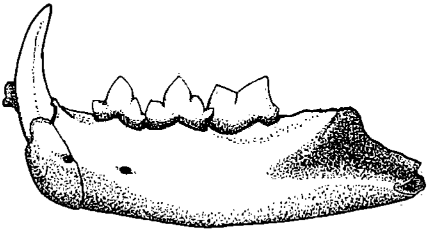

FIGURE 4. Lower jaw of *Felis yagouaroundi* (No. MU 7315), approximately × 1.

the jaw and teeth resemble the jaguarundi and differ from the bobcat and ocelot; therefore we consider the specimen a young adult male jaguarundi.

The jaguarundi is a rare resident in extreme southern Texas today. We know of no records from the Edwards Plateau in historic time or of previous records from Pleistocene deposits of Texas.

Lynx rufus – BOBCAT

Layer C1: 1 upper P4 (7317), a humerus (7318), a femur (7319), other postcranial elements (7320). Layer C2: 1 canine (7388), deciduous teeth as follows: 1 canine, 2 lower carnassials, 1 upper carnassial (7389), 1 ulna (7390). The milk teeth were washed from matrix and are not known to have been associated.

The geographic range of the bobcat includes most of Mexico and the United States. Though much persecuted, bobcats are still common on the Edwards Plateau today.

Bobcat remains have been recorded from several late Pleistocene deposits in Texas (Frank, 1964). In view of their wide range and local abundance, that they are absent from so many well-studied deposits is surprising.

Elephas cf. *E. columbi*

Layer C2: part of a milk tooth (7391), represented by a number of plates washed from a single sack of matrix and belonging to a single tooth. The rest of the tooth was represented by numerous small fragments. Compared with the large series of elephant milk teeth from Friesenhahn Cave at the University of Texas, our plates resemble the smaller ones.

We have followed other authors in referring specimens from very late Pleistocene deposits not identifiable to species to the species *columbi*. As no definite characters separate the several species of American late Pleistocene elephants from the Old World *Elephas*, we see no justification for the continued use of the term *Mammuthus*.

Elephants are common fossils in late Pleistocene deposits of Texas. Schulze Cave is another site where elephants and ancient man have been recorded together.

Odocoileus virginianus — WHITE-TAILED DEER

Layer C1: 1 metacarpal (7321), 1 humerus (7322), part of radius (7323), etc. Layer C2: 1 calcaneum (7392), partial tibia (7393), 2 ulna fragments (7394, 7395), 1 fragmentary metapodial (7396), etc. The fragmentary ulnae and fragmentary metapodial from C2 are from a fawn. Not listed: approximately 15 complete and partial limb bones from the lower level of layer C2, destroyed in carbon 14 test.

Remains of white-tailed deer were scattered sparsely through layers C1 and C2. Deer remains are far more common in layers B and D. No jaws or antlers were recovered in any part of the cave. The metapodial from layer C1 is of a mature animal, as are several of the metapodials and other bones from layer D. All are of white-tailed, not mule deer.

White-tailed deer are plentiful on the Edwards Plateau today. The late Pleistocene and early Recent deposits in Texas contain many records of the species.

Bison sp.

Layer C1: part of an upper molar (7324). Layer C2: lateral toe vestige (7397).

The tooth is from an old animal. The enamel thickness and the size of the enamel cresent suggest that it is from a bull. As tooth sizes are similar in the modern buffalo and the several extinct *Bison* species, the fragmentary tooth cannot be identified to species. On the basis of age it probably belonged to *Bison antiquus* or *B. occidentalis*.

The toe bone is the proximal element of the toe vestige of the front foot. It is well preserved and comparable in detail to the vestigial toe bone of the modern buffalo, but is nearly twice as large. We do not know the range of variation in size of this bone in modern and extinct *Bison*, but the few specimens from modern buffalos available to us are rather uniform.

Equus sp.

Layer C1: 1 upper incisor (7325). Layer C2: 1 sesamoid (7398).

The specimens do not permit specific identification, but do prove the presence of a small species of extinct horse in the cave fauna. The incisor is unworn. Both the incisor and sesamoid are smaller than equivalent bones of *Equus conversidens* Owen from the Slaton Quarry of western Texas.

FAUNAL UNITY

We refer the fauna of the upper part of the Pleistocene deposits of Schulze Cave, layers C1 and C2, to the Schulze Cave Local Fauna. We note but slight difference between the mammalian faunas of the two layers, and the differences are largely quantitative. The faunas of the two layers show virtually no qualitative differences.

Of the 62 species in the two layers, 42 are present in both layers. An additional 12 forms are known each from a single specimen from one layer or the other, and little weight can be placed on their absence from the other layer. The hoary bat material consists of two jaw fragments thought to have belonged to a single individual. Similarly we think the grizzly bear bones from layer C1 belonged to one animal. The two human teeth from layer C2 almost certainly are from a single child. The only species apparently represented in one layer by more than one individual and absent from the other layer are *Pipistrellus subflavus, Spermophilus spilosoma, Neotoma albigula,* and *Vulpes velox.*

Extinct species in the Schulze Cave Local Fauna include only the elephant, horse, and probably the bison. We found the elephant only in layer C2, but bison and horse in both layers. The three extinct species constitute only a small proportion of the total fauna, but form a sizeable proportion of the larger mammal species detected in the cave fauna. Most extinction at the end of the Pleistocene occurred among the large mammals.

FAUNAL SUCCESSION

Although no major qualitative differences are evident in the mammalian faunas of layers C1 and C2, they show quantitative differences. Species now found in more northern and cooler regions are commoner in the lower, older layer while species more typical of warm or semiarid habitat increase in the upper layer. When we consider only species known from 10 or more specimens from the two layers combined, and regard as significant a difference of 20 per cent of the total, we find 13 species more common in layer C1 (Table 3). The total number of specimens from layer C1 is greater

TABLE 3. RELATIVE ABUNDANCE OF SPECIES BY LAYER

Commoner in younger C1 layer		Commoner in older C2 layer	
Sorex cinereus	68%	*Myotis velifer*	60%
Cryptotis parva	70%	*Myotis* cf. *evotis*	67%
Notiosorex crawfordi	62%	*Sylvilagus floridanus*	64%
Perognathus merriami	76%	*Thomomys umbrinus*	89%
Perognathus hispidus	80%	*Geomys bursarius*	64%
Reithrodontomys montanus	61%	*Reithrodontomys fulvescens*	67%
Peromyscus pectoralis	89%	*Reithrodontomys* cf. *fulvescens*	74%
Peromyscus boylii	68%	*Peromyscus maniculatus*	65%
Baiomys taylori	87%	*Microtus* sp.	68%
Onychomys leucogaster	75%	*Zapus princeps*	90%
Sigmodon hispidus	81%		
Neotoma albigula	100%		
Spilogale putorius	63%		

(3,334) than from layer C2 (2,544). Weighing the percentages results only in removing *Notiosorex crawfordi, Reithrodontomys montanus,* and *Spilogale putorius* from the list of mammals significantly more abundant in the younger deposit.

To find the cinereus shrew commoner in the younger layer is surprising, and we cannot explain why the two bats and the cottontail rabbit should be commoner in the older layer. In general the entire local fauna shows a slight but distinct increase in species of mammals adapted to semiarid habitat, and a decrease in species of northern and alpine affinities.

In marked contrast to the slight faunal change between layer C1 and C2 is the abrupt change between layer C1 and layer B. Where 53 species were detected in layer C1, we found only 26 in layer B. The opossum, man, and domestic dog recovered from layer B were not found in layer C1, but man was found in layer C2 and presumably man and dog were present in the vicinity when layer C1 was forming. The only actual addition to the fauna seems to be the opossum. In part the apparent differences between layer C1 and layer B may stem from the smaller collection (some 900 specimens) from the early Recent deposit compared with the more than 3,300 fossils from layer C1.

As noted earlier, all species taken in layer B are also known from the modern fauna of the Edwards Plateau. By contrast we find the following present in C1 but absent from the Recent fauna: three shrews, the mole, long-eared myotis, chipmunk, kangaroo rat, rice rat, western harvest mouse, deer mouse, prairie vole, jumping mouse, red fox, swift fox, ermine, jaguarundi cat, and the extinct elephant, bison and horse.

Disregarding the bats, the following occur in the modern fauna but not in layer C1 or C2: opossum, armadillo, Audubon cottontail, rock squirrel, fox squirrel, beaver, gray fox, ringtail, raccoon, coatimundi, mink, ocelot, collared peccary, pronghorn, and buffalo. Unsuitable habitat in the immediate vicinity of the cave doubtless accounts for the absence in the Pleistocene fauna of some species, such as beaver and mink, and random collection may account for other absences. We have, for example, an upper deciduous P4 of a procyonid from layer C2 that is either *Procyon* or *Nasua* but not certainly identifiable. Nevertheless the absence of the opossum, armadillo, rock squirrel, gray fox, ringtail, collared peccary, and perhaps other forms, is probably significant.

PALEOECOLOGY

Of the 59 extant forms of the Schulze Cave local fauna, 40 now live on the Edwards Plateau or did so in historic times. Five species (*Sorex cinerus, Sorex vagrans, Lepus townsendii, Zapus princeps* and *Mustela erminea*) now occur no nearer the Edwards Plateau than the mountains of New Mexico. Another five species (*Blarina brevicauda, Cryptotis parva, Oryzomys palustris, Peromyscus maniculatus* and *Microtus ochrogaster*) occur 100 miles or more to the east of Schulze Cave and three species (*Spermophilus spilosoma, Dipodomys ordii* and *Reithrodontomys megalotis*) are found 100 miles or so to the west of Schulze Cave. The remaining six forms have varied distributions. *Myotis evotis* has not been taken nearer the Edwards Plateau than southern New Mexico, but probably occurs closer. *Vuples velox,* a fox of the sandy plains, has been taken 200 miles northwest of the Edwards Plateau. *Felis yagouaroundi* inhabits the thickets of eastern Mexico and extreme southern Texas. *Synaptomys cooperi* comes as far south as southern Kansas and northeastern Arkansas. *Tamias striatus* approaches the Edwards Plateau most closely in southern Arkansas. The distribution of the red fox has been confused by introductions by man, but in early historic times it probably came no closer to the Edwards Plateau than southern Arkansas.

Two-thirds of the extant fauna (40 species) are present in the Recent fauna of the Edwards Plateau but one third (19 species) are out of range, sometimes greatly so. The 19 out of range species represent several diverse ecological conditions and geographical regions, but sympatry of species of modern mammalian faunas of central Texas with species now found no closer than the southern Rocky Mountains and the woodlands of southeastern United States is common in late Pleistocene faunas of Texas. For example, the Howard Ranch Local Fauna of Hardeman County, Texas (Dalquest, 1965), is somewhat older than the C2 layer of Schulze Cave. Carbon dates range from 16,775 BP to 19,098 BP. The fauna, though varying in some details, has the same out of range elements: southern Rocky Mountains, northern Great Plains and eastern woodlands. The southern element of the modern Edwards Plateau fauna is lacking in this more northern fauna. *Sorex cinereus* is present in both faunas but the wandering shrew, jumping mouse, and ermine are lacking in the Howard Ranch local fauna. On the other hand the water shrew, *Sorex palustris,* and meadow vole, *Microtus pennsylvanicus,* present in the Howard Ranch Local Fauna were not found at Schulze Cave. The rice rat and *Blarina brevicauda,* species of the eastern lowlands, were present in both local faunas.

Hibbard (1960) postulates climatic conditions in the southern Great Plains that permitted so many species that are now allopatric to live together in a single fauna. The climate was then more uniform, summers cooler and winters warmer, with somewhat greater humidity and no extended periods of subfreezing weather. Dalquest (1965) points out that the presence of the Wisconsin ice sheet in the north would lower summer temperatures, and the absence of cold fronts would result in warmer and more uniform winters. The nature of the Schulze Cave local fauna gives additional support to this thesis and shows that such conditions extended southward at least to southern Texas.

Lundelius (1967) has objected to this explanation because some of species Hibbard and Dalquest thought unable to tolerate bitter winter conditions actually range far northward in the eastern United States. The eastern United States and the Great Plains have sheltered habitats where such mammals may escape the effect of the cold. This is specially true of the burrowing mammals. But these mammals do not now occur on the Great Plains, presumably because of the effects of extreme winter cold. These same species did occur on the Great Plains in the late Pleistocene, associated with species living there now and which are adapted to semiarid grassland environment (spotted ground squirrel, two species of pocket mice, kangaroo rat, grasshopper mouse, etc.). It is the *sympatry* of species on the

Great Plains in the late Pleistocene that must be accounted for. Lundelius (1967) suggests that increased moisture and soil conditions were responsible for the occurrence of the eastern species on the Great Plains in the late Pleistocene, but this explanation is negated by the presence in the same deposits of the species adapted to semiarid grasslands listed above.

The northern limits of range listed by Lundelius (ibid) are mostly east of the Great Plains and out of the effect of the winter cold fronts. The record of the rice rat from Kansas is probably based on an error, and the cotton rat has extended its range northward on the Great Plains only in recent decades (Cockrum, 1952).

The large and varied fauna from Schulze Cave permits detailed consideration of the ecological conditions on the Edwards Plateau and the areas to the west and east in the late Pleistocene. We were especially intrigued by the presence in the Schulze Cave Local Fauna of species now occurring no closer than the southern Rocky Mountains of New Mexico. In the summer of 1966 we spent 6 weeks studying the small mammals in the mountains of northern New Mexico and southern Colorado, with special attention to alpine species found in Schulze Cave and the Howard Ranch local faunas: *Sorex cinereus, Sorex vagrans, Sorex palustris, Microtus pennsylvanicus, Zapus princeps,* and the species associated with them in their alpine habitat.

While the listed species occur in a variety of habitats they all, including the water shrew, are abundant in dense, lush, herbaceous or grassy vegetation where the ground is damp and little or no light reaches the surface of the ground through the dense cover. These species are influenced primarily by the microenvironment. The dense ground cover may be part of a vast alpine meadow, a small area surrounded by spruce forest, or in willow and alder thickets beside a small stream. If conditions are suitable the shrews, meadow vole, and jumping mouse are usually present. Exception is made to the water shrew which does require at least some open water. These species are independent of trees, thickets, or rock cover.

Among the species associated with the mentioned shrews, vole, and jumping mouse are chipmunks, *Eutamias minimus* and *E. quadrivitatus,* golden-mantled ground squirrel, *Spermophilus lateralis,* and voles such as *Microtus montanus* and *M. longicaudus.* The chipmunks seem to require some cover of trees, stumps, or rocks upon which to climb. Presumably some parts of the region stretching between the Edwards Plateau and the southern Rocky Mountains were completely free of trees or rocks, and thus barriers to chipmunks and similar forms. Other alpine mammals of the southern Rocky Mountains include the marmot, *Marmota flaviventris,* red squirrel, *Tamiasciurus hudsonicus,* bushy-tailed wood rat, *Neotoma cinerea,* red-backed mouse, *Clethrionomys gapperi,* and pika, *Ochotona princeps.* These forms are even more restricted to trees or rocky cover and, significantly, are also missing from the late Pleistocene faunas of Texas.

We postulate that in the late Pleistocene the High Plains of Texas and the region stretching to the base of the Rocky Mountains, was similar to a modern alpine meadow. Vegetation consisted of a cover of dense grasses and annuals of a great variety of species. The climate was cool — cool summers and cool winters — but without cold fronts or long periods of subfreezing weather. The ground was damp, probably from fogs and drizzle rather than heavy rains. Cloudy weather probably prevailed in winter and much of the summer also. The masked shrew, wandering shrew, jumping mouse, and similar species occupied most or all of the area between the southern Rocky Mountains on the west and the Edwards Plateau and northern Texas on the east. Aridity, high summer temperatures, and winter cold fronts of the Recent eliminated most of the Pleistocene flora and established the monotonous grassy plains that existed until historic times. Aridity, dry ground, and fewer plant seeds eliminated the alpine species of small mammals that occupied the region in the late Pleistocene.

Detailed studies of reliably dated late Pleistocene faunas of the Trans-Pecos region of Texas are lacking. We suspect that the alpine meadow conditions described extended over the present High Plains and southward to a point west of the Edwards Plateau, and that a desert existed in the Trans-Pecos region east of the Davis Mountains.

The Edwards Plateau lay east of the alpine meadow environment. Conditions on the Edwards Plateau suitable for alpine species were probably limited to marshes and meadows near stream valleys. The land to the west and north must have been the reservoir from which such alpine species as jumping mice and wandering shrews invaded suitable Edwards Plateau habitat. Perhaps only in relatively humid cycles did marshes exist marginal to Paint Creek, near Schulze Cave.

We presume that the climate of the Edwards Plateau when the cave deposits were forming during the late Pleistocene was cooler, more uniform, and more humid. In canyons and deeper-soiled areas, woodlands of oaks, walnut, elm, and other broad-leaved trees grew as they do today. Where the soil was shallow over the limestone, dense and extensive grasslands existed. Most of the species, and the vast majority of individuals found in the Pleistocene deposits of Schulze Cave are typically inhabitants of grasslands or open woodlands. The open woodlands of the Edwards Plateau probably were continuous on the east with woodlands of eastern Texas. The eastern mammals (mole, shrews, pine vole, rice rat, prairie vole, chipmunk, red fox etc.) ranged freely to the vicinity of Schulze Cave.

The only species of the Schulze Cave Local Fauna that are confined to the vicinity of sand are the spotted ground squirrel and the Ord kangaroo rat. Other forms, such as the grasshopper mouse and pocket mice, prefer but are not restricted to sandy habitats. In the late Pleistocene the sand-restricted species probably inhabited the sandy terraces of the streams. The Rio Grande valley to the south was probably the reservoir from which such species could move into suitable habitat. Suitable habitat was probably very limited along Paint Creek, near Schulze Cave, and the kangaroo rat and spotted ground squirrel may have occupied the terraces along the creek only in relatively arid cycles. Both forms are notably rare in the cave fauna.

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