technical paper

Inner Space Cave: Discovery and geological and paleontological investigations

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Abstract

In 1963 a large cave was found by the Texas Highway Department while conducting foundation core drilling for a railroad overpass of Interstate Highway 35 south of Georgetown, Texas. A 2-foot diameter access hole was drilled into the cave. Exploration by highway department personnel and members of the Texas Speleological Association found an extensive cavern underlying the site of the proposed overpass. The landowner, Dr. Laubach, received permission from the Texas Highway Department to develop a commercial cavern under the highway, and it was named Inner Space Cave. The cavern is located in the Cretaceous Edwards Formation and within the Balcones Fault Zone, both known for having caves and sinks.

Further exploration by paleontologists discovered numerous bones of prehistoric and extinct vertebrate species. Fossil vertebrates were recovered from five localities in the cave complex. These five locations are the positions of former entrances to the cave that were open at different times during the late Pleistocene. Radiocarbon dates show that three of the entrances were open 23,000; 15,000; and 13,000 years before present.

The fossils represent the fauna that lived in Texas during the late Pleistocene and include a number of extinct species as well as extant species no longer found in central Texas. Some differences in the faunas from the five localities may indicate changes in the fauna through time.

Discovery

During the spring of 1963 when the Texas Highway Department (currently named the Texas Department of Transportation) was conducting foundation core drilling for a railroad overpass south of Georgetown, Texas, a large cavern was discovered (Sansom, 1996). The overpass was a part of the new Interstate Highway 35 bypass of Georgetown. The staff geologist for the Bridge Division of the Texas Highway Department, James Sansom, was contacted and exploration of the cavern was done following the drilling of a two-foot diameter access hole into a large subterranean room. Texas Highway Department personnel from both the Bridge Division and District 14 conducted exploration and surveying of the larger portions of the cave. Subsequently more intensive exploration and mapping were done by local spelunkers affiliated with the Texas Speleological Association (Figure 1).

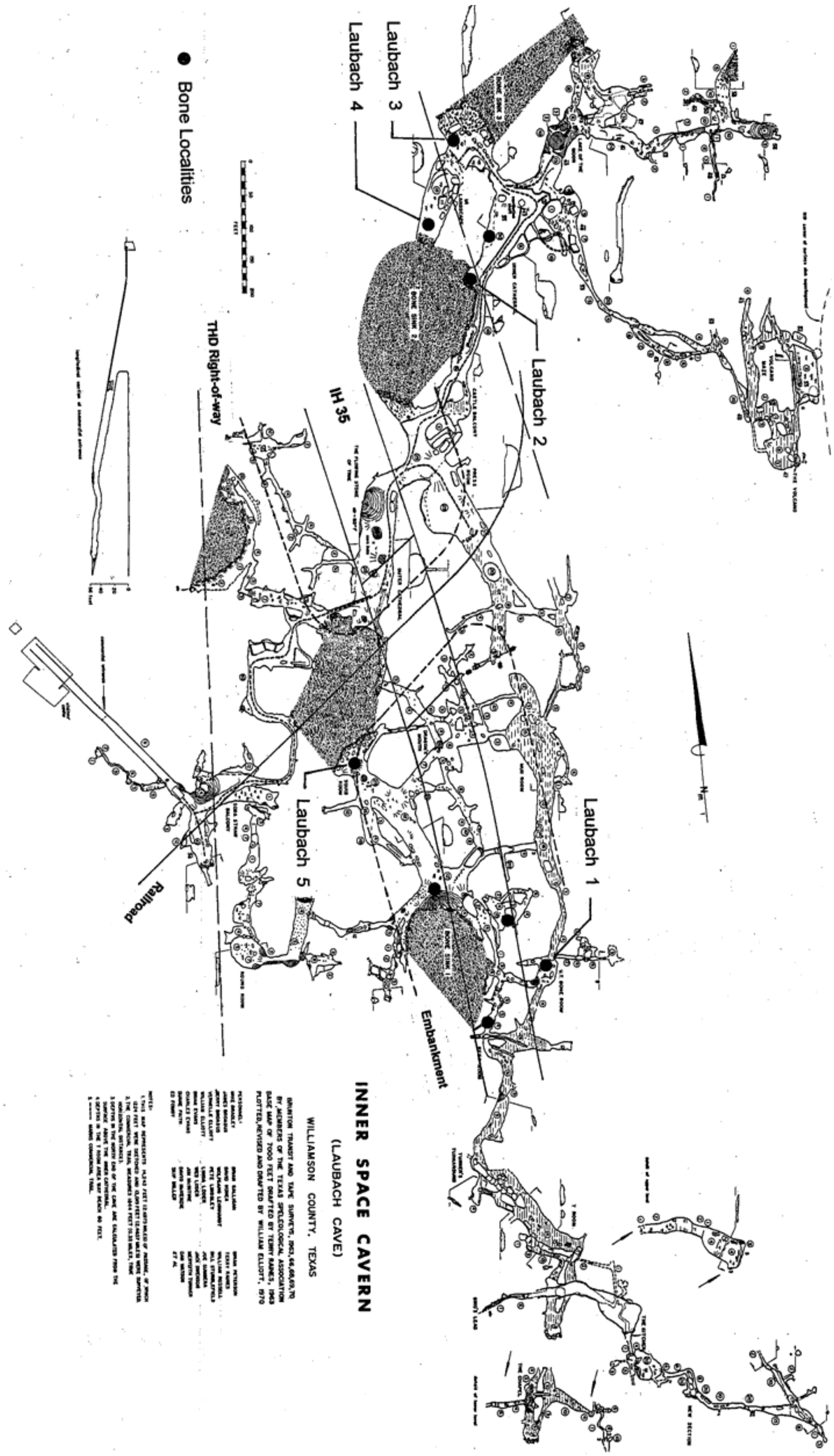

Figure 1. **Map of Inner Space Cavern with Bone Locations and the route of IH 35 and its overpass over the Georgetown Railroad super-imposed on it (cavern map prepared by members of the Texas Speleological Association).**

Geological Investigation

The first people to enter the cave were Jack Bigham, District 14 technician; James Sansom, Bridge Division geologist; Horace Hoy, Bridge Division foundation engineer; and two engineers with District 14, Bill Schultz and Lawrence Schultz. The five people who entered the cave for the first time were lowered into the cave on the kelly of the auger rig that had drilled the access hole. Jim Cole of District 14 drilled this hole (Figure 2). When core driller Sylvan Turner first drilled into the cave, he drilled through 33.5 feet of limestone bedrock. His bit broke through the ceiling of the cave and fell approximately 25 feet to the floor of the cave where it locked up in some flowstone.

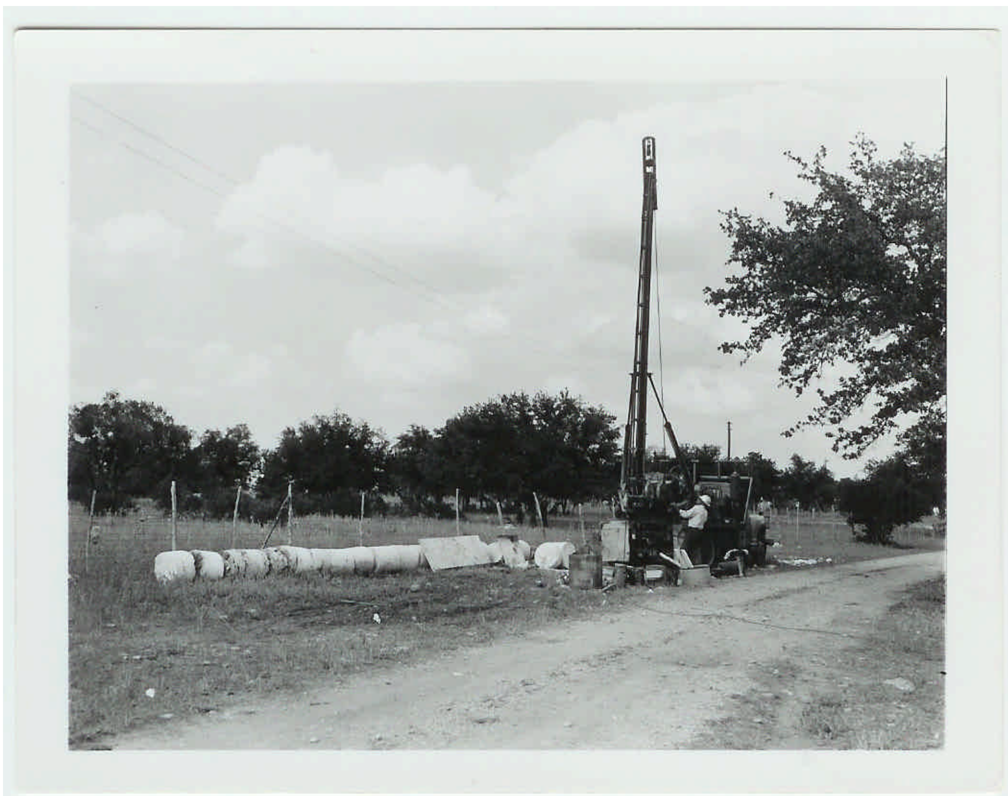

Figure 2. View of the auger rig of the Texas Highway Department District 14 and driller, Jim Cole, when the two-foot access hole to cavern below had been completed (photo taken by Jack Lewis, photographer with the Travel and Information Division of the Texas Highway Department, 1963).

Several trips were made into the cave by District 14 personnel including a survey crew that included Bill Johnson, Don Burch, and Leroy Sumner that mapped the extent of the larger more accessible portions within the right-of-way of the proposed highway and overpass (Figure 3). In the initial exploration of the cave, the air was stagnant and no natural openings to the outside were found. Smoke from a match and old Blue Dot flash bulbs used in photography would not disperse. The survey crew, accompanied by James Sansom, had to go to the surface several times to get fresh air. The numerous core holes drilled into the cave were used to lower light bulbs on cords to provide light for the survey (Figure 4).

Figure 3. **View of the inside of the Discovery Room of the cavern where Bill Johnson, Texas Highway Department Survey Crew Chief, was being lowered into the cavern on the auger rig kelly through the two-foot diameter access hole. James Sansom was holding the guide rope on the kelly (photo taken by Jack Lewis, photographer with the Travel and Information Division of the Texas Highway Department, 1963).**

After the first exploration and surveying was completed, local members of the Texas Speleological Association and paleontologists visited the cave. Dr. Bob Slaughter of Southern Methodist University was the first paleontologist to collect and study the fossil bones. This resulted in the first publication (Slaughter 1966) on the material recovered from the locality later designated Laubach 1. Later Dr. William Akersten, then a graduate student, and Dr. Ernest Lundelius, both of the University of Texas, explored and recovered animal bones from various localities in the cave (Lundelius, 1985).

Texas Highway Department engineers determined that the hard limestone rock that overlies the cave was of sufficient strength to support the planned overpass, and Dr. William W. Laubach, the landowner, received permission from the Texas Highway Department to develop the cavern commercially into what is now called Inner Space Cavern. An inclined shaft was excavated on Dr. Laubach's land outside and adjacent to Texas Highway Department right-of-way on the west side of Interstate Highway 35 as a new entrance to the cave. Considerable construction was done to create walkways that extend under the Interstate Highway 35 right-of- way and to the east side of it, as shown by Figure 1. On the east side of Interstate Highway 35 a vertical shaft was drilled for an outside air source on the northeast end of the commercial section of the cave.

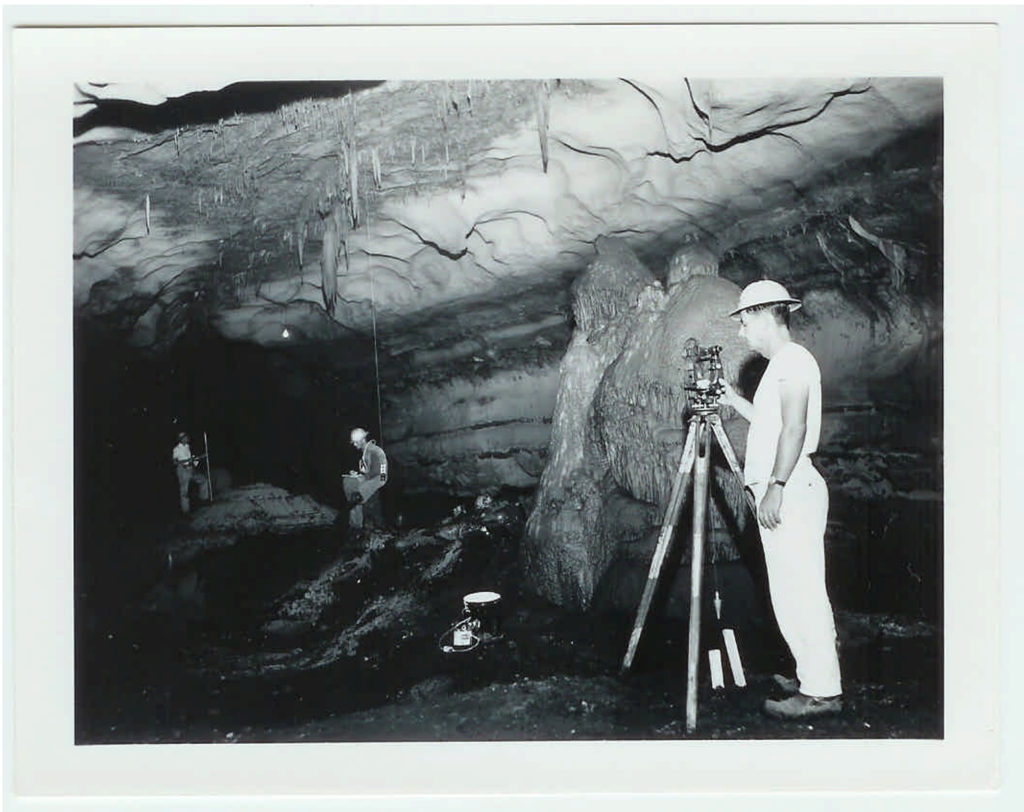

Figure 4. Survey crew working inside the Discovery Room with Leroy Sumner operating the survey instrument, Bill Johnson recording survey data, and James Sansom holding survey rod at a distance. Note light on cord hanging down from roof of cavern providing light for surveying (photo taken by Jack Lewis, photographer with the Travel and Information Division of the Texas Highway Department, 1963).

Geologic Setting

Inner Space Cavern was formed in the Edwards Formation of Lower Cretaceous age, as were numerous caves in Central Texas. The Edwards Formation is composed of a high percentage of calcium carbonate—it is very susceptible to dissolution by acid water over time. Hence caves, sinks, and other solution features are common in this rock unit. The cavern is located in the Balcones Fault Zone, which increases the potential for rainwater to flow into the formation by way of faults, joints, and other fractures and to dissolve the calcium carbonate to form solution features. During periods of high rainfall the water table often rises in the cave and remains for a period of time until it recedes. Geologists suspect in the past, when some of the collapsed areas in the cave were open to the surface, that high rainfall washed in sediment and moved through the caverns rapidly and abraded the cave walls and ceiling in addition to dissolving them. The extensive deposits of red clay in the cavern are derived from terra rossa soils that were washed in from the surface. These red-brown soils characteristic of karst areas are found as relict soils over the Edwards Plateau. Terra rossa soils have been mapped in the Central Texas area by Dr. Keith Young (Young, 1986).

Cave passages are commonly controlled by faulting, cross faulting, and associated joints in the country rock, and this is true of Inner Space Caverns (Figure 1). In the vicinity of the cave, faults have been mapped that strike from N 8 to 23 degrees E (Collins, 1997). Alignments of the predominant structure in the mapped portion of Inner Space Cave range from N 21 to 27 degrees E, which is reflected in the orientation of the passageways of Inner Space Cavern. The displacement along faults of the Balcones Fault Zone near the cavern in Williamson County is reported to be up to 150 feet. When Sansom was lowered into the cavern during the early exploration, he observed that the upper 10 to 15 feet of the rock exposed in the access core hole resembled the limestone of the Georgetown Formation.

The exposure was a dry chalky white nodular limestone of uniform lithology that is typical of the Georgetown Formation. Below this, the rock abruptly changed to a honeycombed, cherty, massive, dolomitic limestone typical of the Edwards Formation. Water was observed flowing out of the vuggy openings, down the wall of the core hole, and dripping into the cavern below. The cave is restricted to the Edwards Formation.

During exploration of the cave, numerous stalagmites, stalactites, flowstone, soda straws, and other speleothems were observed. Many of the speleothems were stained with various shades of red. The floor of much of the cave was covered with red mud and, in places, bat guano where the floor was not covered with water. Numerous nodules and discontinuous beds of chert as well as invertebrate fossils are exposed in the cave walls. Five closed collapsed sinks that were most likely natural openings at some time in the past were mapped by the spelunkers. As shown in Figure 1, most of the animal bones found in the cavern are in the vicinity of the sinks. The bones identified by Dr. Ernest Lundelius and others are discussed in this paper.

Paleontological Investigations

Inner Space Cavern (Laubach Cave) is an important vertebrate fossil locality because it contains fossiliferous deposits from several different time periods in the late Pleistocene and gives an idea of the changes in the fauna of this area. In addition, the chronology of the speleothem growth record overlaps that of the vertebrate fossils and makes possible a comparison of the climatic interpretations based on the two kinds of data.

Location of bones and taphonomy

All the fossil bones are associated with debris cones that mark former entrances to the cave system. They are rare or absent in areas away from the old entrances which is in accordance with the observations that, aside from bats and a few birds that practice echolocation, most animals that enter caves voluntarily do not go far from the lighted areas of the cave. To date five localities within the cave system have produced fossil bones (Lundelius, 1985). The localities with Texas Memorial Museum locality numbers are as follows: Laubach 1 (TMM 40673), Laubach 2 (TMM 40722), Laubach 3 (41343), Laubach 4 (TMM 41505), and Laubach 5 (TMM 41465) (Figure 1).

Laubach 1 is located in the southern part of the cave system at the edge of Bone Sink 1. Bones were collected from several places around the edge of this debris cone (Figure 1). In some places they were concentrated (Figure 5). It is presumed that the bones from the various places around the debris cone are the same age. They were reported by Slaughter (1966).

Laubach 2, located on the northeast edge of Bone Sink 2 (Figure 1), is the only site known to have had an opening to the surface during historic time as evidenced by the presence of some modern garbage along its edge when the cave was first entered by investigators. The entrance shaft is currently plugged by sediment and contains the partial skeleton of a mammoth. Below is a characteristic debris cone with some bone on the surface. These bones are covered by a thin layer of travertine. At the base of the cone is a basin in which one small excavation

Figure 5. Skulls of the extinct peccary (Platygonus compressus) in place at Laubach 1.

was carried out. The material from the surface of the debris cone, the excavation in the basin, and the mammoth lodged in the shaft of the original opening may not be same age.

Laubach 3 is located at the southwest edge of Bone Sink 3 (Figure 1). This is at the base of a debris cone of large limestone boulders that have been heavily cemented by travertine. The fossiliferous sediments are not cemented but seem to be closely related to the part of the debris cone that underlay the cemented boulder layer. The sediments are darker colored than those from the other fossiliferous deposits in the cave, and the bone is stained a dark brown. This is in contrast to the light cream color of bones from the other localities in the cave.

Laubach 4 is located on the north flank of the same debris cone as Laubach 2 (Bone Sink 2). A small trench excavated at the base of the debris cone produced some evidence of aboriginal human activity in the form of a few flint flakes but no recognizable artifacts. These are cataloged in the collections of the Texas Archaeological Research Laboratory under the number 41WM 231. Remains of a number of small animals were also recovered (Table 1).

Laubach 5 is located on the southeast flank of a debris cone approximately 220 feet (67.6 meters) north-northwest of Bone Sink 1. The fauna is similar to that from Laubach 1 and 2.

Age of the faunas

Three radiocarbon dates are available from Laubach localities 1, 2, and 3. They are all based on bone, mostly long bones, of small mammals that have the denser cortical bone. The dates are based on the method developed by Haynes (1968). In this technique, cortical bone is powdered and leached *in vacuuo* with acetic acid before the washed and dried bone is reacted a second time with HCl or phosphoric acid. Dilute acetic acid reacts immediately with calcite and much more slowly with the bone apatite, thereby removing secondary carbonate first but not appreciable amounts of the indigenous carbonate apatite's CO_3^{-2}. When the bone powder is reacted with stronger acids as HCl or H_3PO_4, these reagents dissolve the carbonate apatite and release CO_2, which is subsequently used for radiocarbon dating. The resulting age measurement is an "inorganic bone carbonate date" and contrasts with radiocarbon dates on the organic phase of bone or teeth, the collagen fraction. The procedure is effective for removing pedogenic and groundwater-derived calcium carbonate. However, subsequent studies (Surovell, 2000) have found that the indigenous carbonate in bone apatite will exchange at the molecular level and that bone apatite dates may still be compromised by unknown amounts of molecular-level, secondary carbonate contamination of the hydroxyapatite crystal. In limestone terrains, the common error will be dates being too old, but this is not always the case and there currently exist no criteria to determine the direction or the magnitude of the error. This new research indicates that there is still likely to be contamination of the bone crystallites by carbonate from surrounding sediments and that these dates should be regarded as minimum estimates of the ages of the units dated (Stafford, 1998; Stafford and others, 1991).

The fauna

The faunas recovered to date from the various localities in the cave are summarized in Table 1. The reptiles and amphibians have not been studied in detail, and the faunal lists of these groups should be regarded as provisional. The fauna is typical of the late Pleistocene faunas of Texas, but the presence of assemblages of different ages in one restricted area provides some information on possible faunal changes during the late Pleistocene.

Table 1. Faunal list from Laubach Cave

Taxon	*Laubach locale* 1	2	3	4	5
Class Amphibia					
Rana pipiens (leopard frog)		x	x		
Class Reptilia					
Terrapene carolina (Eastern box turtle)		x			
Sceloporus sp. (fence lizard)		x	x		
Coluber sp. (racer)		x	x		
Elaphe sp. (rat snake)		x			
Heterodon sp. (hog-nosed snake)		x			
Pituophis sp. (bull snake)		x	x		
Thamnophis sp. (garter snake)		x	x		
Agkistrodon contortrix (copperhead)		x	x		
Crotalus sp. (rattlesnake)		x	x		x
Class Mammalia					
Didelphis marsupialis (o'possum)		x	x		
Tadarida brasiliensis (Brazilian free-tail bat)			x		
Myotis sp. (little brown bat)			x		
Cryptotis parva (least shrew)		x		x	
Blarina carolinensis (Southern short-tailed shrew)				x	
Felis onca (jaguar)	x		x		
*Homotherium serum (saber-toothed cat)		x			
Mephitis mephitis (striped skunk)		x			
Spilogale putorius (spotted skunk)			x		
*Canis dirus (dire wolf)			x		
Canis latrans (coyote)			x		
Urocyon cinereoargenteus (gray fox)			x		
*Tremarctos floridanus (spectacled bear)			x		
*Mammuthus sp. (mammoth)		x			x
*Equus sp. (horse)		x	x		
*Platygonus compressus (extinct peccary)	x		x		x
Odocoileus sp. (deer)			x		
*Tetrameryx shuleri (four-horned antelope)			x		x
*Camelops sp. (camel)		x			
*Dasypus bellus (large armadillo)			x		
*Glyptotherium floridanum (glyptodont)			x		
*Megalonyx jeffersonii (ground sloth)			x		
Cynomys ludovicianus (prairie dog)	x		x		
Microtus sp. (vole)		x	x	x	
Neotoma sp. (packrat)		x	x		
Peromyscus sp. (deer mouse)		x	x		
Sigmodon hispidus (cotton rat)		x	x		
Geomys sp. (gopher)		x	x	x	
Perognathus hispidus (hispid pocket mouse)				x	
Perognathus sp. (pocket mouse)				x	
Dipodomys elator (Texas kangaroo rat)			x		
Dipodomys sp. (kangaroo rat)		x			
Lepus californicus (jackrabbit)		x	x		x
Sylvilagus sp. (cottontail)	x	x	x		

* connotes extinct taxa

The oldest assemblage is from Laubach 3, dated at 23,230±490 years before present. It contains remains of several species not found in other localities in the cave (Table 1). These are spectacled bear (Tremarctos floridanus) (Figure 6), glyptodont (Glyptotherium floridanum) (Figure 7), large armadillo (Dasypus bellus), dire wolf (Canis dirus) (Figure 8), an extinct species of pronghorn, Jefferson's ground sloth (Megalonyx jeffersonii), and Brazilian free-tailed bat (Tadarida braziliensis) (Figure 9), and Texas kangaroo rat (Dipodomys elator). It also has remains of species found in some of the other Laubach localities: flat headed peccary (Platygonus compressus), black tailed prairie dog (Cynomys ludovicianus) (Figure 10), jaguar (Panthera onca) (Figure 11), and an extinct species of horse (Equus sp.). Toomey (1994) in a brief summary of the fauna pointed out the difference in the fauna from Laubach 3 and mentioned that it contained many species with tropical or subtropical living relatives.

All of these animals are known from other localities of late Pleistocene age in Texas with the exception of the Brazilian free-tailed bat. Its presence in this fauna is significant. It is the common cave bat in central Texas today. Toomey (1993, 1994) pointed out that this bat, living in Texas caves today, is totally absent in later Pleistocene and early Holocene deposits of all other caves for which we have faunas. It appears in the sequence in Hall's Cave in Kerr County at about 2,000 years before present. The date of its appearance in Laubach 3 at 23,000 years before present coincides with the end of the last interstadial (the warm period, dating approximately 23,000 to 58,000 years before present) preceding the last glacial maximum of the Wisconsinan glaciation (Musgrove and others, 2001). These data strongly suggest that this bat was unable to tolerate the climate in central Texas during the last glacial maximum. The reason for its seemingly late return to Texas as recorded in Halls Cave is not known.

The disappearance of the Brazilian free-tailed bat with the onset of the last glacial maximum raises the possibility that the ranges of some of the other species found only in Laubach 3 might also have been restricted at that time. However, these species are known from other localities in Texas that date within the last glacial maximum. The Texas kangaroo rat may be another species that suffered a range constriction at the end of the last interstadial. It currently lives only in a limited area in north central Texas. The record in Laubach 3 indicates a subsequent restriction in its range sometime in the last 23,000 years.

Two species, Tremarctos floridanus and the glyptodont, are known from late Pleistocene faunas from the eastern part of the United States, including the Gulf Coastal Plain and Mexico (Kurtén and Anderson, 1980; Gillette and Ray, 1981). They are not known from the Edwards Plateau. Their presence in Laubach Cave, located at the eastern edge of the Edwards Plateau, marks the western limit of their known distribution during the late Pleistocene and suggests environmental differences at that time between the Gulf Coastal Plain and the Edwards Plateau.

The faunas of Laubach 1, 2, and 5 will be discussed together as they are very similar in species composition. In addition, the radiocarbon dates of Laubach 1 and Laubach 2 are close (15,850±500 years before present and 13,970±319 years before present, respectively) although they do not overlap. They both fall in the last glacial maximum.

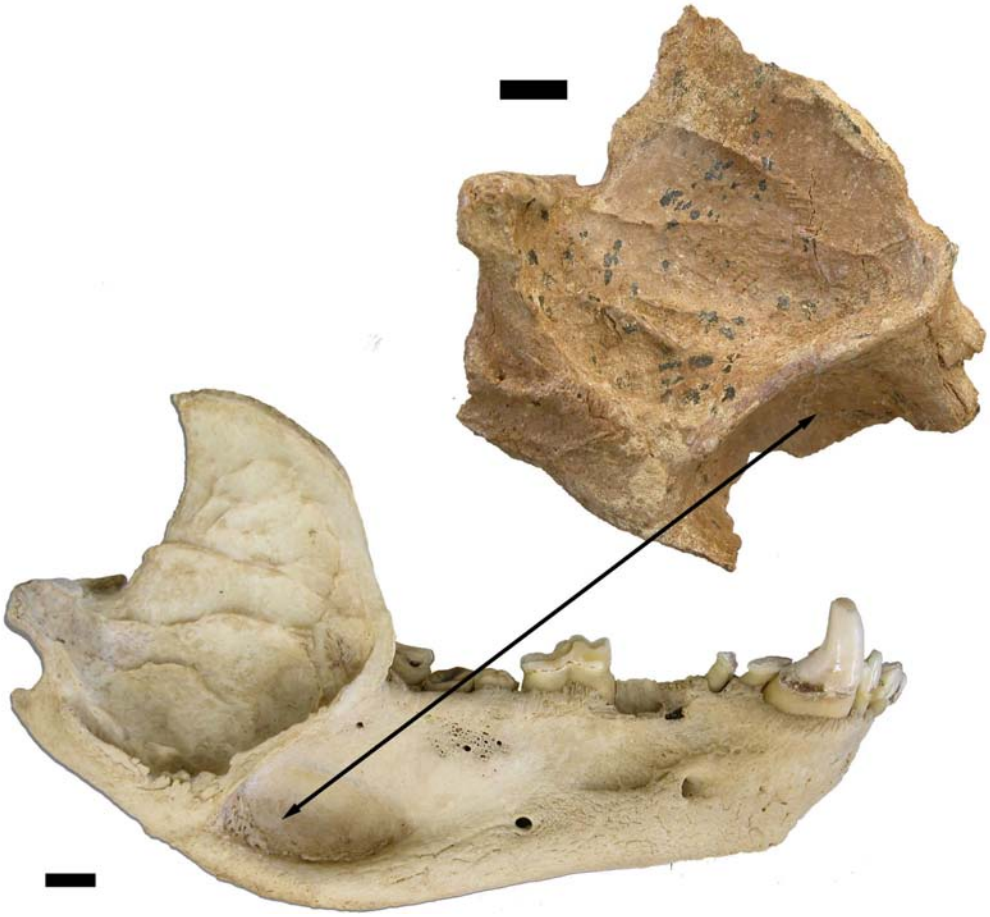

Figure 6. **<u>Tremarctos</u> <u>floridanus</u> (TMM 41343-153). Posterior part of right lower jaw with reconstruction of main part of the ramus compared with the lower jaw of modern <u>Tremarctos</u> <u>ornatus</u>, below. Note the characteristic depression ahead of the masseteric fossa. Scale bars are 1 cm.**

Figure 7. **<u>Glyptotherium</u> <u>floridanum</u> (TMM 42343-2). Scute. Scale bar is 1 cm.**

Figure 8. **Canis dirus (TMM 41343-67). Left upper premolar, lingual view. Scale bar is 1 cm.**

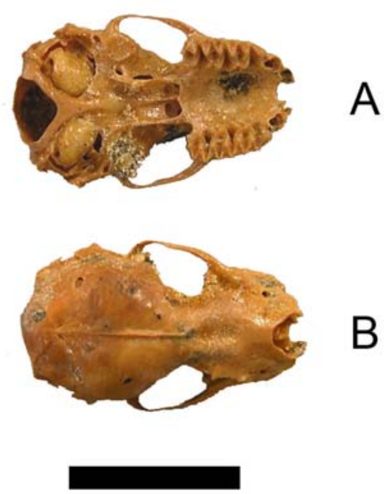

Figure 9. **Tadarida brasiliensis (TMM 41343-765). Skull, ventral view (A) and dorsal view (B). Scale bar is 1 cm.**

Figure 10. Cynomys ludovicianus (TMM 40673). Palate. Scale bar is 1 cm.

Figure 11. Panthera onca (TMM 40673-49). Anterior end of right lower jaw with canine and fourth premolar. Scale bar is 1 cm.

The fauna of Laubach 1 was described by Slaughter (1966). It contains a large sample of the large extinct peccary (Platygonus compressus), jaguar (Panthera onca), bob cat (Lynx rufus), camel (Camelops sp.), and mammoth (Mammuthus columbi). The sample of the peccary conforms to other samples of Platygonus compressus from other areas very well. The jaguar is within the size range of Pleistocene jaguars from North America, which were somewhat larger than their modern counterparts. The fauna from Laubach 2 is similar in that it has the camel, cottontail (Sylvilagus sp.), and packrat (Neotoma sp.) and also has horse, skunk, and several small rodents.

The trench in the basin north of Laubach 2 was relatively unproductive. A deciduous canine of the saber tooth cat, (Homotherium serum) (Figure 12), was found here. This animal is widespread in North America but is abundant only at Friesenhahn Cave in Bexar County. This locality has produced a large sample of this animal including a substantial number of juveniles of all ages that suggests that Homotherium used Friesenhahn Cave as a den for the young (Graham, 1976; Rawn-Schatzinger 1983, 1992). A cave in Cannon County, Tennessee, has also produced a juvenile specimen of Homotherium (Rawn-Schatzinger and Collins, 1981). The deciduous canine from Laubach Cave indicates that this cave was also used as a den for juveniles.

The most common animal is the large extinct peccary, Platygonus compressus. Slaughter's study of the sample from Laubach 1 demonstrated no differences from samples of comparable age from other parts of the United States. This species had a very wide distribution in North America during the late Pleistocene. Kurtén and Anderson (1980) pointed out that cave faunas very commonly contain Platygonus bones indicating that they probably used caves for shelter at times, as do modern peccaries. Many of the specimens are from immature animals.

Several extant species represented in the fauna of Laubach Cave are no longer found in central Texas and suggest that climatic and environmental changes may have constricted their ranges. One is a vole (Microtus sp.). Members of this group of rodents are generally found today to the north and east of central Texas in more mesic areas, although one relict population was found in Kerr County in the 1930s (Bryant, 1941). Voles are present in all Pleistocene faunas of Texas and indicate a climate more mesic than present. Another such species is the southern short tailed shrew (Blarina carolinensis) now found from east Texas eastward. The interpretation of more rainfall and/or a lower evaporation rate is supported by the growth rates of speleothems from the cave (Musgrove and others, 2001). They record faster growth of speleothems during the last glacial maximum than in the Holocene which is attributed to an increased availability of water.

The prairie dog (Cynomys ludovicianus) is present in Laubach 1 and 3. This animal is no longer present in central Texas, but there are historic records near Mason and in Bexar County (Hall and Kelson, 1959; Davis, 1974). They occur in a number of Pleistocene faunas in Texas but are rare in Holocene faunas. Prairie dogs are burrowers that need soil at least one meter thick. Their disappearance indicates that the areas with sufficiently thick soils for their burrowing activities have disappeared over most of central Texas.

Another characteristic of Pleistocene faunas that is not well represented in the Laubach Cave assemblages is the co-occurrence of species that are now allopatric (that is, species whose geographical distributions do not now overlap). These faunas have been termed non-analog

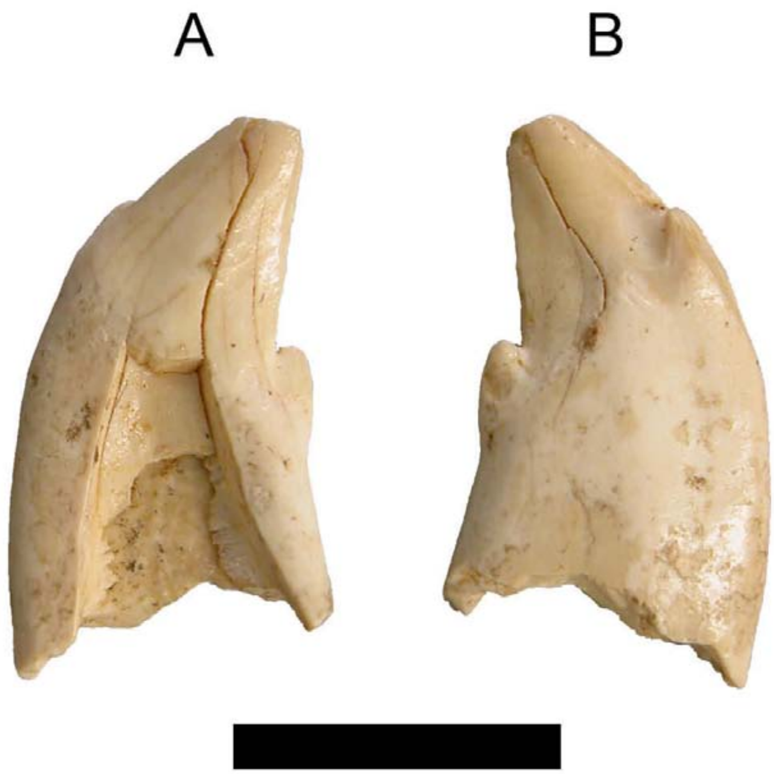

Figure 12. Homotherium serum (TMM 40722-56). Deciduous left lower canine, labial view, (A) and lingual view (B). Scale bar is 1 cm.

because they have no modern distributional analogs. Only two pairs of such species are currently known to occur in the Laubach Cave deposits, both involving the Texas kangaroo rat (Dipodomys elator). The vole (Microtus sp.) and the southern short tailed shrew (Blarina carolinensis) are both known from Laubach 3 along with the Texas kangaroo rat, but neither is found today in the same area as the Texas kangaroo rat. These assemblages have been interpreted as an indication that Pleistocene climates were less seasonal than the present (Hibbard, 1960; Lundelius, 1974). This is based on the observation that the species involved in such associations that are primarily northern in their distributions appear to have southern limits controlled by the summer aridity and temperature maxima while the species that are primarily southern in their distribution appear to have their northern limits controlled primarily by the winter temperature minima. The reason for the scarcity of non-analog associations in the Laubach Cave deposits is almost certainly the poor samples of the small animals currently available.

Conclusions

Inner Space Caverns (Laubach Cave) located in the Balcones Fault Zone in Williamson County is a complex system of passages whose orientations indicate strong fault and joint control. Vertebrate fossils are found at five locations in the cave marked by debris cones that mark former entrances. The faunas from three localities have radiocarbon dates of 23,230; 15,850; and 13,970 years before present. The faunas are not exactly the same and may indicate changes in the regional fauna during the late Pleistocene. The faunal assemblages indicate more mesic conditions during the last glacial maximum, and the presence of now allopatric species indicate a more equitable climate at that time.

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