A NEW PLEISTOCENE VERTEBRATE FAUNA FROM AUSTIN, TEXAS

A Senior Scholars Thesis

by

KER SHUN YOUNG

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

April 2009

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Approved by:

Research Advisor: Thomas Stidham
Associate Dean for Undergraduate Research: Robert C. Webb

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ABSTRACT

A New Pleistocene Vertebrate Fauna from Austin, Texas. (April 2009)

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A new fossil vertebrate fauna consisting of fish, snake, and small mammalian remains was discovered near McKinney Falls State Park in Austin, Texas. Identification and analysis of the species in the cave deposit reveals paleoclimatic and paleoenvironmental changes between the late Pleistocene (over 11,500 years ago) and the present. This site is unique in the very large number of snake fossils (422 skeletal elements) compared to the mammalian fossils (79 skeletal elements) collected. This makes the site a prime candidate for the first fossil multispecies snake hibernaculum ever found in the world. Hibernacula are places in which large groups of animals, including snakes, gather to spend the winters in hibernation. Identification of the snake species is based on the morphology of the trunk vertebrae, and the fossils currently are identified as racers (*Coluber constrictor* or *Masticophis* sp.), garter snakes (*Thamnophis* sp.) or water snakes (*Nerodia* sp.) and Baird's rat snake (*Elaphe bairdi*). Those snakes commonly form multispecies hibernacula in shelters today. However, snakes do not form multispecies hibernacula in Central Texas today, but only in more northern colder regions.

Identification of the mammalian fauna of the site is primarily based on morphology of teeth, and the fossil teeth are harvest mice (*Reithrodontomys* sp.), voles (*Microtus* sp.), southern bog lemmings (*Synaptomys cooperi*), pocket gophers (*Geomys* sp.), black-tailed jackrabbit (*Lepus californicus*), shrews (*Notiosorex* sp. or *Sorex* sp.), and a bat. All of these mammalian taxa also have been found in other Pleistocene sites around Austin and across central Texas. However, some of the mammalian species in this cave deposit do not occur in Texas after the end of the Pleistocene and are currently located in the eastern and northern regions of North America. The changes in the geographic distribution of mammals and the inferred changes in snake behavior in this cave likely are biological response to the shift to warmer climates in Central Texas since the end of the Pleistocene.

DEDICATION

This thesis is dedicated to my father, Sin Fook Young, mother, Ean Sein Tan, sister, Allyn Young, brother, Glenn Young, and last but not least, Dr. Thomas Stidham.

ACKNOWLEDGMENTS

I wish to thank all those who have encouraged, supported, and helped me in writing this thesis. I thank Dr. Thomas Stidham for collecting the sediments and samples from the site, and helping me edit this senior thesis and abstract. I thank Dr. Darryl deRuiter for allowing me to borrow skeletal specimens from the Zooarcheology Lab at the Department of Anthropology.

NOMENCLATURE

M	Molar
P	Premolar
TAMU	Zooarcheology Lab, Department of Anthropology, Texas A&M University, College Station, TX

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CHAPTER I

INTRODUCTION

A new Pleistocene vertebrate cave fauna site recently was discovered near McKinney Falls State Park in Austin, Texas. The cave site was exposed after the construction of a road cut exposed the cave site (Figure 1) (pers. comm. T. Stidham, January, 2009). The road cut has resulted in the removal of most of the Ozan Formation surrounding the cave and parts of the Pleistocene deposit (pers. comm. T. Stidham, January, 2009). The cave is situated in the Cretaceous Ozan Formation that surrounds a Cretaceous igneous extrusion known as Pilot Knob near McKinney Falls State Park (Proctor et al., 1974). The cave also is located near the Balcones Fault, a fault line that divides the Western Edwards Plateau from the Eastern Gulf Coastal Plain (Lundelius, 1986). The fault line (Figure 2) within Texas begins near Del Rio and extends East, then Northward towards Dallas (Collins, 1994). The geology of the fault shows a distinction between the Cretaceous carbonates of the Edwards Plateau, which lies adjacent to the clastic material of the Gulf Coastal Plain (Lundelius, 1986). Fossil sites located near the fault are usually fluvial terraces or cave deposits accumulated within limestone, shale, or chalk (Lundelius, 1986).

This thesis follows the style of Journal of Vertebrate Paleontology.

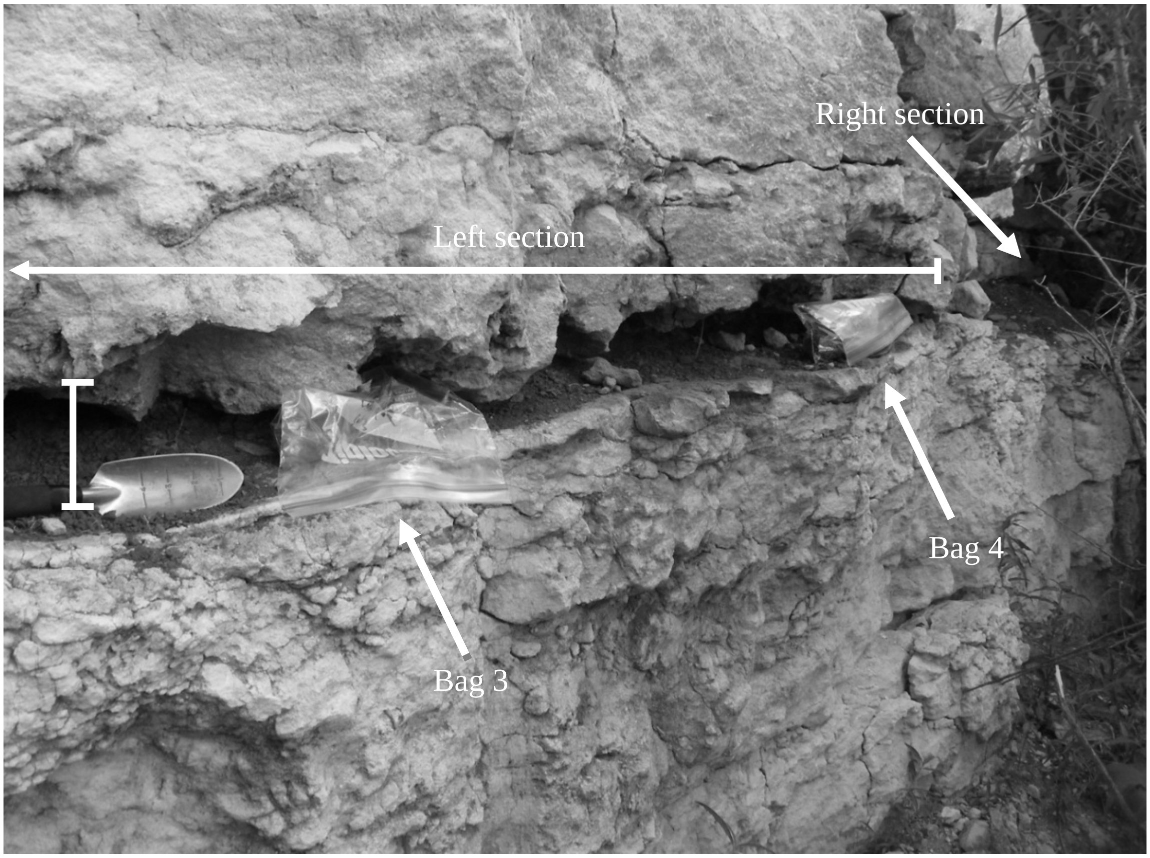

FIGURE 1. The left section of the cave near the McKinney Falls State Park. Measured 4.6 m from left to right end. The right end of the karst pinches off and reopens onto the right section. Scale bar is 10 cm.

Fossil vertebrates found in late Pleistocene sites around Texas usually exhibit three general attributes: species existing during the late Pleistocene that have now undergone complete extinction, species still extant to this day with substantial geographic distribution change, and extant species that still exist locally in Central Texas (Lundelius, 1985). Notable cave sites in Texas with faunas from the late Pleistocene or Rancholabrean North America Land Mammal Age include Hall's Cave (Toomey, 1992), Laubach Cave (Lundelius, 1985) and Zesch Cave (Sagebiel, 1998) (Figure 2). While extinct species may reveal how the general climate and environment might have changed, details based on their tolerance levels to environmental change is harder to

FIGURE 2. General locations of late Pleistocene cave site in Texas. **1**, the recently discovered cave site near McKinney Falls State Park; **2**, Laubach Cave; **3**, Zesch Cave; **4**, Hall's Cave. The Balcones Fault Line represented by a bold grey line.

interpret (Lundelius, 1985). Extant species, generally those with spatial distribution change, provide better information on environmental changes (Lundelius, 1985). Usually, such extant species are microfaunas belonging to a group such as rodents, with species including *Synaptomys cooperi*, *Sorex cinereus* (Graham, 1997), and nearly all species of *Microtus* (FAUNMAP working group, 1994). Zesch Cave located near

Mason, Texas, reveals all three attributes of the late Pleistocene fossil sites (Sagebiel, 1998). Zesch Cave contains *Microtus pennsylvanicus, Synaptomys cooperi,* and *Sorex cinereus* (Sagebiel, 1998). All three of these species no longer occur in Texas today (FAUNMAP working group, 1994). This pattern is also present in another cave site called the Laubach Cave, now known as Inner Space Cavern, and that cave also possesses *Microtus* fossil forms that are no longer found in Texas (Lundelius, 1985). Changes in distribution of such microfaunas have suggested that the environment in Central Texas was much cooler and humid during the late Pleistocene (Toomey, 1992). Additionally, movements and dispersal of mammals during the Pleistocene and Holocene have been rather common events (Graham, 1997). However, not all species dispersed around the same time, and the directions of the dispersal also are different (Graham, 1997). *Synaptomys cooperi* and *Sorex cinereus*, in particular, rapidly dispersed to Northern regions while *Microtus pennsylvanicus* seems to have dispersed at a slower rate (Graham, 1997). Other species, such as *Microtus montanus,* dispersed westward, while *Tamias striatus* dispersed eastward (Graham, 1997).

The Pleistocene and Holocene are the two most recent epochs in Earth's history. The Pleistocene Epoch extends from 1.83 million years ago to 11.5 thousand years ago, while the Holocene Epoch began 11.5 thousand years ago and extends up to present day (Gibbard and Kolfschoten, 2004). Studies of paleoclimatic changes during these epochs are usually focused on glaciation events (Hart, 2000). Glacial and interglacial cycles are global events that affected worldwide temperature and usually lasted tens of thousands of years (Gibbard and Kolfschoten, 2004). Indicators used to find climatic glacial changes include pollen, vegetation (Hart, 2000), and Oxygen isotopes (Shackleton and Matthews, 1977). Additionally, glaciations cycles may be named differently in different parts of the world; in North America the last glacial cycle was named the Wisconsin glacial (Zeuner, 1959). While glacial cycles bring about global reductions in temperature, interglacial cycles are periods with raised global temperature (Gibbard and Kolfschoten, 2004). Several glacial and interglacial cycles took place during the Pleistocene Epoch. The Wisconsin glacial cycle ended the Pleistocene Epoch and began the Holocene interglacial, which continues up until this day (Gibbard and Kolfschoten, 2004). The implication of the global reduction in ice shows that the Earth's temperature has increased during the Holocene interglacial, and resulted in the dispersal of some rodent species northward.

Hibernacula are places in which groups of animals gather and hibernate together, usually to endure cold conditions. This behavior is exhibited today by certain groups of snakes such as racers (*Coluber constrictor*), striped whip snakes (*Masticophis taeniatus*), pine snakes (*Pituophis melanoleucus*), and rattlesnakes (*Crotalus viridis*) (Parker and Brown, 1973). Since understanding the behavior of prehistoric life-forms is difficult by just studying fossils, modern examples and interpretations based on such examples are often utilized (Breithaupt and Duvall, 1986). Studies on *Nerodia harteri* have shown that the snake species ideal body temperature ranges from 26°C-32°C (Greene, 1993), indicating a relatively ideal high body temperature. Another study on *Scytalus cupreus* also reveals an ideal body temperature ranging from 26°C-28°C, although individuals may remain active around 20°C (Fitch, 1960). However, *Scytalus cupreus* will usually become less active at body temperatures below 10°C (Fitch, 1960). Temperatures from *Scytalus cupreus* hibernacula also reveals interior air temperature ranging from 4°C-11°C, a temperature range that was considerably warmer than air at the exterior of the hibernacula (Fitch, 1960), indicating how snakes may form hibernacula to survive cold weather. Other species of snakes that form hibernacula during cold conditions include *Coluber constrictor* and *Thamnophis sirtalis* (Brown and Parker, 1976). A hibernaculum may involve a single species or multiple species hibernaculum (Werler and Dixon, 2000). In the study on *Scytalus cupreus*, the snake species will commonly form hibernacula with other species of snakes including *Coluber constrictor* and *Thamnophis sirtalis* (Fitch, 1960). Up to this day, the only known fossil site with a snake aggregation is an Oligocene site in a White River Formation at Wyoming that contains an individual of *Ogmophis* and two *Calamagras* individuals (Breithaupt and Duvall, 1986). Therefore, when identifying fossil snake multispecies hibernacula, characteristics that are looked for in a hibernacula site are species of snakes known to form multispecies hibernacula, and a large abundance of snakes in the site as opposed to finding snakes fossils that do not form hibernacula today or small amounts of snake fossils.

CHAPTER II

MATERIALS AND METHODS

The cave site located near McKinney Falls State Park is separated into two sections, from which eight bags of sediments were collected; four from the left section and another four bags from the right section (Figure 2). Each sample collected from the cave site was collected (by Thomas Stidham) where bones were concentrated. The sediments were then screen washed with a #40 sieve in a Calgon/water solution. Through the microscope, I then sorted out bone from the sieved sediments into vials designated for either bone or sediment. The vertebrate bones that are identifiable were mounted on a pin and identified accordingly. All the bones pin mounted were entered into a spreadsheet (Appendix 1) and sequentially identified down to the lowest level of taxonomic hierarchy possible, preferably to species.

Identification of mammalian skeletal elements was primarily based on morphology of teeth. In microtine rodents' teeth, features that were examined are Christmas tree-like shaped with alternating triangles. In rodents with brachydont type teeth, features that were examined are the arrangement of the cusps and tooth wear. Lagomorphs (or rabbits) are larger than most mammalian fauna in the site, therefore distinguishing them from any other mammal initially was based on size. Part of the rabbit's skull was also used to identify the species. When looking for shrews in the sediments, I looked for red staining on the labial surface on the lower molars and occlusal surface of upper molars.

Mammalian specimens from this site were also compared to contemporary specimens from the Zooarcheology Lab of the Department of Anthropology at Texas A&M University (TAMU). Mammalian specimens used to compare to fossils from this site are TAMU-2-82 (*Lepus californicus*), TAMU-2-239 (*Sylvilagus aquaticus*), TAMU-2-338 (*Microtus ochrogaster*), TAMU-2-314 (*Peromyscus pectoralis*), and TAMU-2-105 (*Reithrodontomys megalotis*).

Snake vertebrae were identified and distinguished based on morphology of thoracic vertebrae. Features that were examined in thoracic vertebra are hemal keels, neural arches, neural spines, prezygophyseal accessory process, epizygapophyseal spines, and hypaphophysis. Contemporary snake specimens from the TAMU were used to compare with fossil snakes from the cave site. Snakes specimens used are TAMU-4-63 (*Lampropeltis mexicanus*), TAMU-4-63 (*Lampropeltis calligaster*), TAMU-2-52 (*Thamnophis sirtalis*), TAMU-2-42 (*Nerodia flavigaster*), TAMU-4-49 (*Masticophis flagellum*), TAMU-4-73 (*Elaphe obsoleta*), TAMU-4-75 (*Elapidae micrurus*), TAMU-4-60 (*Thamnophis elegans*), TAMU-4-35 (*Corais erebennus*), TAMU-4-65 (*Crotalus sp.*), TAMU-4-21 (*Opheodrys aestivus*), and TAMU-4-36 (*Agkistrodon contortrix*).

CHAPTER III

RESULTS

Systematic paleontology

Subphylum VERTEBRATA Cuvier, 1812

incertae sedis

Material – b4s8, b4s11, b6s3, b7s25, b7s106, b7s114, b7s118, b7s126, b7s128, b7s136, b7s138, b7s139, b7s140, b7s141, b7s142, b7s143, b7s144, b7s157, b7s175, b7s176, b7s205, b8s34, b8s42, b8s54, b8s72, b8s77, b8s79, b8s84 (all specimens are unidentified bone fragments).

Description – Skeletal elements comprise of bones that are too fragmented and provides no help for identification purposes. These skeletal elements comprise the most numerous bone types found in the fossil collection, some of which are nothing more than a tiny fragment less than $1mm^2$.

Discussion – In the fossil burial process and preparation, there is always a chance that fossils could get fragmented for various reasons, such as roof falls in cave sites. Some bones may contain matching pairs in the site that may eventually form a larger bone piece although some bones are so fragmented that it becomes nearly impossible to match the bone fragments.

Class OSTEICHTHYES Huxley, 1880

Figure 3

Material – b7s215 (centrum).

Description – A single amphicelous centrum with no articulating ribs. The centrum possesses a distinctive hourglass shape within the centrum. The size of the centrum is less than 1mm in length, width, and height.

Discussion – Identification based on single centrum was insufficient to progress beyond class level. Since there is a creek near the cave site, there could have been be a flood event where the fish was washed in or predators could have brought the fish into the cave.

Figure 3. Lateral view of fish centrum (b7s215). Scale bar equals 1mm. CT-cotyle.

Class REPTILIA Laurenti, 1768

Order SQUAMATA Oppel, 1811

Suborder SERPENTES Linnaeus, 1758

Family cf. COLUBRIDAE Oppel, 1811

Figure 4.A – D

Material – b1s1 (caudal vertebra), b1s2 (caudal vertebra), b1s5 (tooth), b1s6 (tooth), b1s7 (caudal vertebra), b1s9 (tooth), b1s10 (tooth bearing skull bone), b1s11 (caudal vertebra), b1s12 (tooth) b1s14 (caudal vertebra), b1s15 (tooth), b1s16 (tooth), b1s17 (caudal vertebra), b1s18 (tooth), b1s19 (caudal vertebra), b1s20 (caudal vertebra), b1s21 (tooth), b1s22 (tooth), b1s23 (tooth bearing skull bone), b1s25 (tooth), b1s27 (tooth), b1s28 (tooth), b1s29 (tooth bearing skull bone), b1s30 (tooth), b1s31 (tooth), b1s35 (tooth), b1s36 (tooth bearing skull bone), b1s37 (caudal vertebra), b1s38 (tooth), b1s39 (caudal vertebra), b1s40 (caudal vertebra), b1s41 (tooth), b1s42 (tooth), b1s47 (tooth), b1s49 (tooth), b1s50 (caudal vertebra), b1s65 (caudal vertebra), b1s83 (caudal vertebra), b1s84 (rib), b1s89 (rib), b1s91 (caudal vertebra), b4s10 (snake tooth), b4s12 (snake tooth), b4s15 (rib), b5s2 (tooth), b5s8 (vertebra), b5s10 (caudal vertebra), b5s15 (tooth bearing skull bone), b5s18 (caudal vertebra), b5s22 (caudal vertebra), b5s23 (tooth bearing skull bone), b5s24 (tooth bearing skull bone), b5s32 (rib), b5s44 (vertebra), b5s46 (vertebra), b6s1 (caudal vertebra), b6s2 (tooth), b6s3 (tooth), b6s4 (tooth), b7s6 (tooth), b7s7 (tooth), b7s8 (tooth), b7s9 (tooth), b7s10 (tooth bearing skull bone), b7s11 (tooth bearing skull bone), b7s12 (tooth bearing skull bone), b7s14 (tooth bearing skull bone), b7s15 (tooth bearing skull bone), b7s21 (rib), b7s24 (rib), b7s26 (vertebral condyle), b7s35 (caudal vertebra), b7s54 (caudal vertebra), b7s58 (thoracic vertebra), b7s67 (vertebral condyle), b7s68 (vertebral condyle), b7s70 (caudal vertebra), b7s72 (vertebral condyle), b7s78 (vertebral condyle), b7s79 (caudal vertebra), b7s83 (vertebral condyle), b7s93 (caudal vertebra), b7s100 (vertebral condyle), b7s101 (vertebral condyle), b7s103 (vertebral condyle), b7s104 (caudal vertebra), b7s112 (caudal

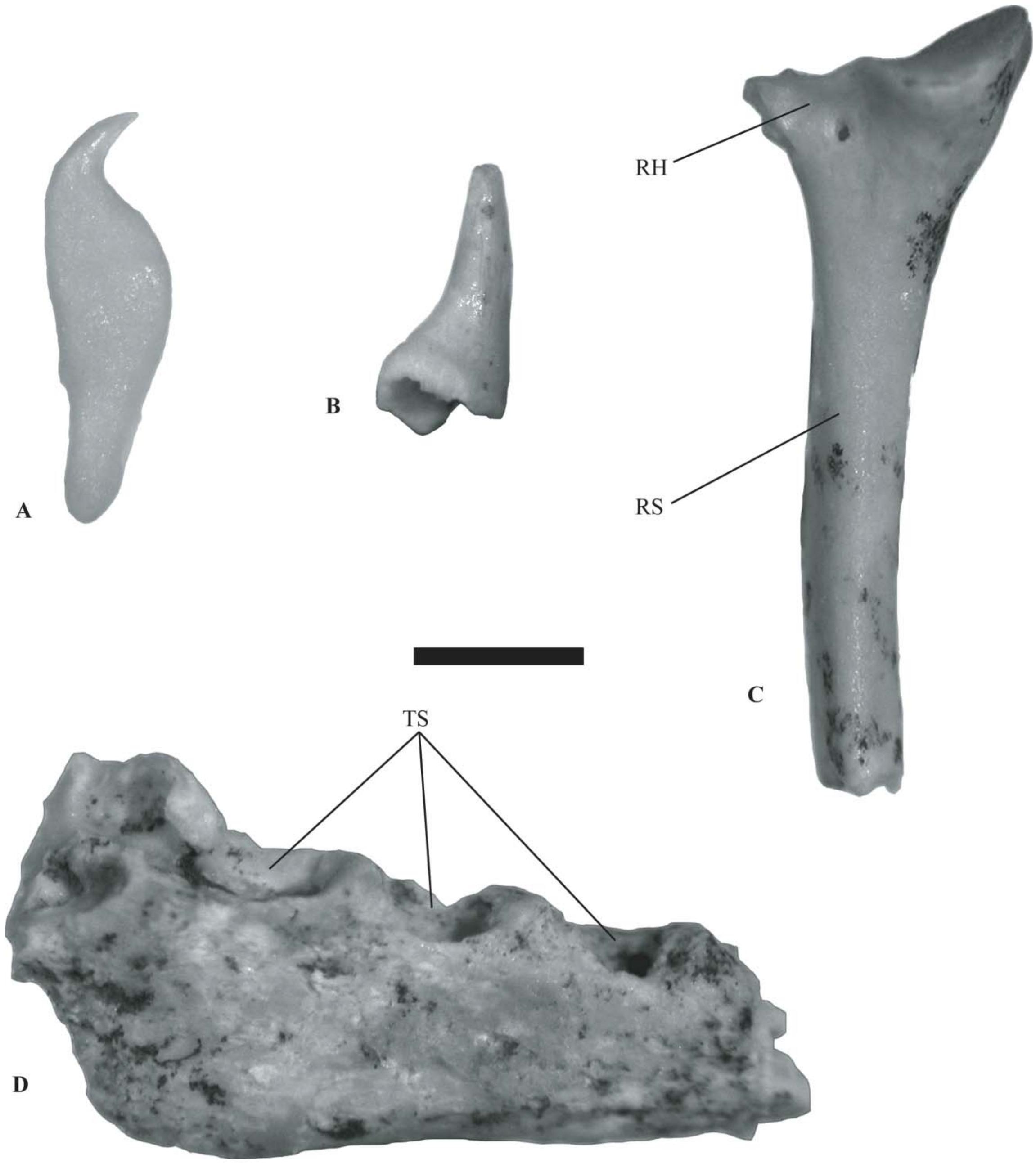

FIGURE 4. Miscellaneous snake skeletal elements. **A**, Lateral view of fang-like tooth (b6s8). **B**, Lateral view of tooth (b1s21). **C**, Rib (b7s21). **D**, Lateral view of tooth-bearing skull bone (b7s12). Scale bar equals 1mm. RH-rib head; RS-rib shaft; TS-tooth socket.

vertebra), b7s113 (caudal vertebra), b7s122 (caudal vertebra), b7s127 (caudal vertebra), b7s146 (caudal vertebra), b7s147 (rib), b7s148 (rib), b7s149 (rib), b7s150 (rib), b7s151 (rib), b7s152 (rib), b7s154 (rib), b7s156 (vertebral condyle), b7s158 (tooth bearing skull bone), b7s159 (rib), b7s160 (rib), b7s161 (rib), b7s162 (rib), b7s163 (rib), b7s165 (rib), b7s167 (caudal vertebra), b7s168 (rib), b7s171 (rib), b7s172 (rib), b7s173 (caudal vertebra), b7s174 (rib), b7s177 (rib), b7s178 (rib), b7s179 (rib), b7s180 (rib), b7s183 (rib), b7s184 (vertebra), b7s185 (rib), b7s186 (rib), b7s187 (rib), b7s188 (rib), b7s189 (rib), b7s190 (rib), b7s191 (rib), b7s192 (rib), b7s193 (rib), b7s194 (rib), b7s195 (rib), b7s196 (tooth bearing skull bone), b7s197 (rib), b7s198 (rib), b7s199 (rib), b7s200 (tooth bearing skull bone), b7s201 (rib), b7s202 (tooth bearing skull bone), b7s203 (rib), b7s204 (rib), b7s206 (rib), b7s207 (rib), b7s208 (rib), b7s209 (rib), b7s210 (vertebral condyle), b7s211 (caudal vertebra), b7s212 (caudal vertebra), b7s214, (caudal vertebra), b7s216 (caudal vertebra), b8s4 (tooth), b8s5 (tooth), b8s25 (caudal vertebra), b8s32 (tooth bearing skull bone), b8s35 (tooth bearing skull bone), b8s38 (tooth), b8s39 (tooth bearing skull bone), b8s55 (tooth), b8s57 (tooth bearing skull bone), b8s63 (tooth bearing skull bone), b8s64 (tooth), b8s68 (caudal vertebra), b8s73 (tooth), b8s75 (tooth bearing skull bone), b8s76 (caudal vertebra), b8s83 (tooth), b8s94 (rib).

Description – Miscellaneous snake elements (ribs, vertebral condyles, teeth, tooth bearing skull bones, and caudal vertebrae) are common in the site. The snake teeth are often cone shaped and slightly curved to the posterior of snake skulls. Occasional striations are found at the base of the teeth. Another variation of snake teeth found in the site are fang-like teeth. The fang-like teeth possess a bulb shaped extension with hooks at the end of the fang. Tooth bearing skull bones are often found in the site often with no teeth. The tooth bearing skull bones are relatively narrow with distinct round or occasionally rectangular shaped holes where the tooth was. Snake caudal vertebrae found in the site are generally smaller than the thoracic vertebrae and are narrower when viewed laterally. In addition, unlike thoracic vertebrae, all caudal vertebrae possess a pair of hemal keels often with a pair of hypaphophysis. Snake ribs are long and curved bones with a capitulum or rib head at the proximal end of the rib that articulates with the vertebra. Condyles are broken parts of the snake vertebrae and are half spheres.

Discussion – All of the miscellaneous snake skeletal elements are hypothesized to belong to colubrid snakes due to the fact it is the only family of snakes present at the site. Most of the literature on snake identification is primarily based on thoracic vertebrae or entire skeletons, with little work being done on other snake skeletal elements. It is extremely hard to distinguish snake species based on morphologies of tooth, teeth bearing skull bone, or rib due to overtly similar morphologies. Condyles are extremely similar among snake taxa and can only be tentatively identified if the entire centrum is present. It may be possible to distinguish caudal vertebrae to certain taxa of snakes but since most caudal vertebrae obtain from the site are too fragmented and small, identification becomes very hard. Measurements of the miscellaneous snake skeletal elements are also not as helpful due to that fact that snakes grow throughout their life.

Family COLUBRIDAE Oppel, 1811

Genus COLUBER Linnaeus, 1758 or MASTICOPHIS Baird & Girard, 1853

Figure 5.A – D

Material – b1s44, b1s46, b1s52, b1s53, b1s54, b1s55, b1s56, b1s57, b1s58, b1s59, b1s61, b1s62, b1s63, b1s66, b1s67, b1s68, b1s70, b1s71, b1s72, b1s73, b1s74, b1s75, b1s77, b1s78, b1s79, b1s81, b1s82, b1s85, b1s86, b1s87, b1s88, b1s90, b1s92, b1s93, b1s94, b1s95, b1s97, b1s98, b1s99, b2s1, b2s2, b2s3, b2s4, b2s5, b2s6, b2s7, b2s8, b2s9, b2s10, b2s11, b2s12, b2s13, b2s14, b2s15, b2s16, b2s17, b2s18, b2s19, b2s20, b2s21, b2s22, b2s23, b2s25, b2s27, b2s28, b2s29, b4s3, b4s4, b4s5, b4s6, b4s7, b5s5, b5s11, b5s19, b5s20 ,b5s21, b5s25, b5s28, b5s29, b5s30, b5s31, b5s34, b5s40, b5s45, b5s47, b7s29, b7s31, b7s33, b7s38, b7s41, b7s42, b7s44, b7s45, b7s47, b7s48, b7s49, b7s50, b7s51, b7s52, b7s53, b7s56, b7s57, b7s60, b7s62, b7s64, b7s65, b7s66, b7s69, b7s71, b7s73, b7s74, b7s75, b7s80, b7s82, b7s84, b7s86, b7s89, b7s90, b7s94, b7s95, b7s96, b7s97, b7s98, b7s99, b7s105, b7s108, b7s109, b7s110, b7s115, b7s116, b7s117, b7s120, b7s121, b7s125, b7s129, b7s131, b7s132, b7s133, b7s135, b7s166, b7s169, b7s181, b8s10, b8s16, b8s17, b8s22, b8s27, b8s28, b8s29, b8s41, b8s44, b8s66, b8s90, b8s93, b8s95, b8s96, b8s99, b8s100 (All specimens are thoracic vertebrae.)

Description – Overall dimensions of vertebrae are usually characterized as being longer than wide when viewed dorsally, ventrally, and laterally, and possess a slender build. Hemal keels of vertebrae are generally thin and flat with no distinct hypaphophysis. Neural arches of vertebrae are generally medially vaulted. Neural spines are straight and long, being twice as long as it is tall. Prezygophyseal accessory processes are also relatively elongated. An epizygapophyseal spine also protrudes from the posterior portion of the neural arch.

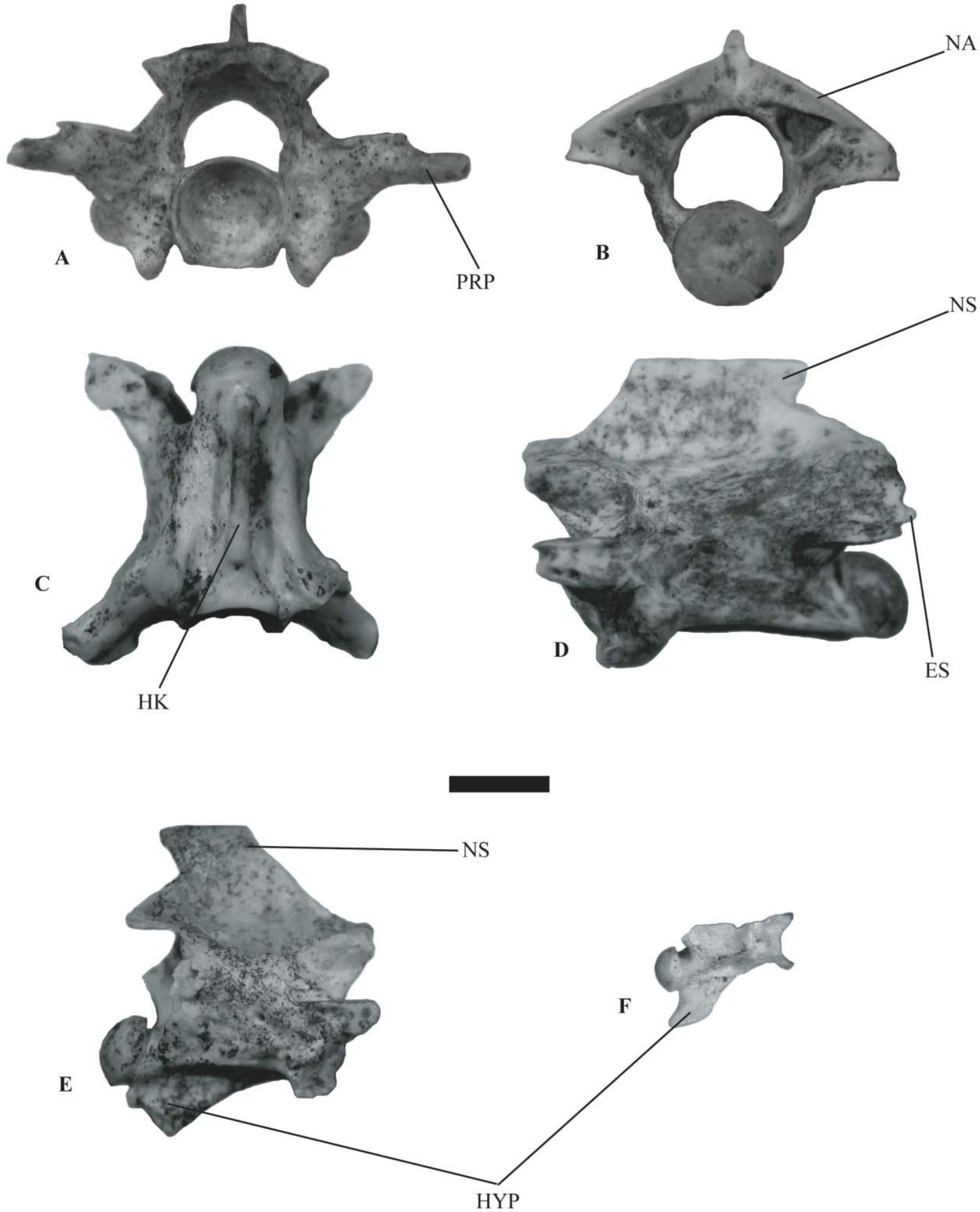

FIGURE 5. Snake vertebrae. **A**, Anterior view of *Coluber constrictor* or *Masticophis* sp. (b8s16). **B**, Posterior view of the same (b2s10). **C**, Ventral view of the same (b2s10). **D**, Left lateral view of the same (b2s1). **E**, Right lateral view of *Thamnophis* or *Nerodia* sp. (b7s107). **F**, Centrum *Thamnophis* or *Nerodia* sp. (b7s27). Scale bar equals 1mm. ES-Epizygapophyseal spine; HK-Hemal keel; HYP-Hypaphophysis; NA-Neural arch; NS-Neural spine; PRP-Prezygophyseal accessory process.

Discussion – Up to this day, no one has been able to distinguish *Coluber* and *Masticophis* vertebrae from another due to similarity in morphology (Parmley, 1986). The species of *Coluber*, if present, would be *Coluber constrictor* since it is the only species of *Coluber* in Texas in both Pleistocene (Holman, 2000) and today (Tennant, 1998). Both species' vertebrae have a thin and flattened hemal keel with no distinct hypaphophysis (Holman, 2000). Neural arches of both species also are medially vaulted with neural spines being twice as long as it is tall along with epizygapophyseal spines that protrude posterior to the neural arch (Holman, 2000). Additionally, both species also have prezygophyseal accessory processes that are relatively elongated (Holman, 2000). The species present at the cave site may be one or both of the species.

Genus ELAPHE Wagler, 1833

Elaphe bairdi Yarrow, 1880

Figure 6

Material – b1s96, b3s1, b7s46, b8s31, b8s62, b8s92 (all specimens are thoracic vertebra.)

Description – The vertebrae are very robust and are characterized as being wider than long when viewed ventrally, dorsally, and laterally. The hemal keels are distinct and wide with no hypaphophysis. Neural arches are relatively vaulted on the posterior end of the vertebrae. Neural spines are usually as tall as it is high, with the posterior edge of the neural spine etched, while the anterior edge of the neural spine are relatively straight. The vertebrae also possess no epizygapophyseal spines. The neural spine was measured to be 1.5 mm in height.

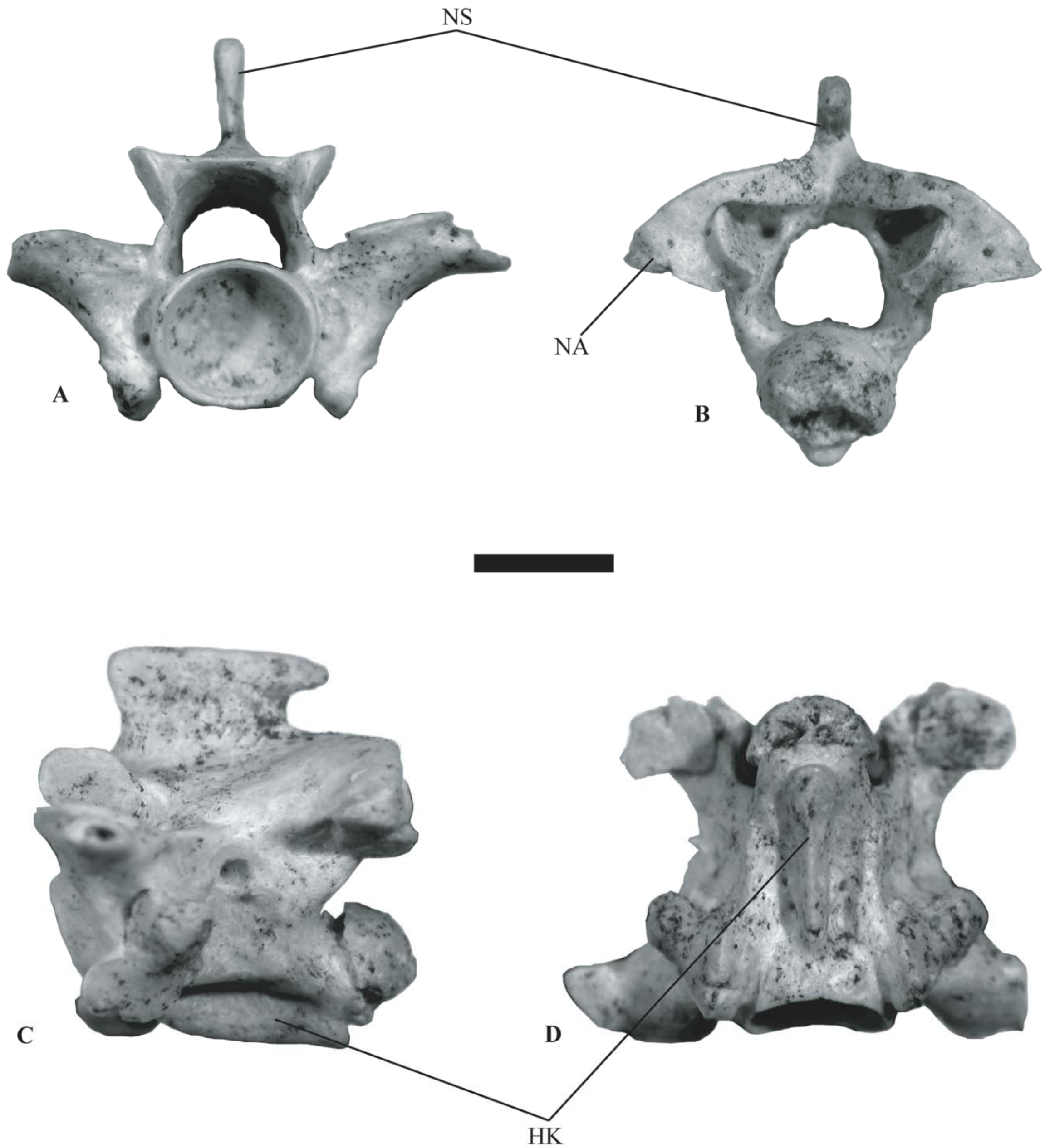

FIGURE 6. Vertebrae of *Elaphe bairdi*. **A**, Anterior view of *Elaphe bairdi* (b3s1). **B**, Posterior view of the same (b3s1). **C**, Left lateral view of the same (b3s1). **D**, Ventral view of the same (b3s1). Scale bar equals 2mm. HK-hemal keel; NA-Neural arch; NS-Neural spine.

Discussion – The vertebrae of *Elaphe* are generally wider and more robustly built compared to the vertebrae of *Coluber* or *Masticophis* (Holman, 2000). The hemal keels are also generally wider than that of *Coluber* or *Masticophis* (Holman, 2000). There are three possible genera of snake that could match the robust features of the vertebrae: *Elaphe*, *Lampropeltis*, and *Pituophis* (Parmley, 1986). Vertebrae of *Pituophis* possess notches on both sides of the neural spine, unlike *Lampropeltis* and *Elaphe* that only possess a notch on the posterior side (Parmley, 1986). *Elaphe* differs from *Lampropeltis* in that neural arches of the posterior side the vertebrae of *Elaphe* are more vaulted than that of *Lampropeltis* (Parmley, 1986). Of all species of *Elaphe* in North America, only 3 species of *Elaphe* occur in Texas (Werler and Dixon, 2000). The only species with an average neural spine height that matches the height of the neural spine of the vertebrae found in the site is *Elaphe bairdi* (Parmley, 1986:fig. 2). Another feature that differentiates *Elaphe bairdi* from a common species found in Texas, *Elaphe guttata*, is the morphology of the neural spine (Parmley, 1986). Neural spines of *Elaphe bairdi* are generally straight compared to vertebrae of *Elaphe guttata* that have thicker edges along the dorsal portions of the neural spines (Parmley, 1986).

Genus THAMNOPHIS Fitzinger, 1843 or NERODIA Baird & Girard, 1853

Figure 5.E – F

Material – b1s8, b1s13, b1s51, b1s60, b1s64, b1s69, b1s76, b4s13, b4s14, b4s16, b4s17, b4s18, b5s1, b5s3, b5s6, b5s7, b5s12, b5s16, b5s17, b5s27, b5s33, b5s35, b5s36, b5s37, b5s38, b5s39, b5s41, b5s42, b5s43, b5s48, b5s49, b7s27, b7s32, b7s33, b7s34, b7s36, b7s37, b7s39, b7s40, b7s43, b7s55, b7s61, b7s63, b7s81, b7s85, b7s87, b7s88, b7s91, b7s102, b7s130, b7s134, b7s137, b7s145, b7s153, b7s164, b7s170 (All specimens are thoracic vertebra.)

Description – Overall dimensions of vertebrae are cube-like. The vertebrae possess a distinct blade-like hypaphophysis located anterior to the condyle. The neural spine is generally twice as long as is high and neural arch is medially vaulted.

Discussion – All of the vertebrae collected are either fragmented or lacking parts of the vertebra, such as prezygophyseal accessory process and/or posterior neural arch. Therefore, identification of the vertebrae to either genus was rather difficult. However, one distinct feature of all the vertebrae from the collection is the distinctive blade-like hypaphophysis that are not found in the rest of the snake vertebrae collection. Several genera of snakes from the Family Colubridae that possess a hypaphophysis at the posterior end of the vertebra are *Neonatrix*, *Regina*, *Storeria*, *Nerodia*, and *Thamnophis* (Holman, 2000). *Neonatrix* is only found in Miocene fossil collections and are now extinct (Holman, 2000). Although *Regina* existed during the Pleistocene, no fossil *Regina* was ever recovered from Texas (Holman, 2000). Hypaphophysis of *Storeria* has a more rectangular shape unlike the blade-like hypaphophysis found in the cave site (Holman, 2000: fig. 134). *Thamnophis* is closely related to *Nerodia* (Holman, 2000) and vertebrae are hard to separate.

Class MAMMALIA Linnaeus, 1758

incertae sedis

Figure 7

Material – b1s4 (metapodial), b4s9 (metapodial), b7s5 incisor), b6s5 (metapodial), b6s6 (caudal vertebra), b6s7 (metapodial), b7s16 (phalanx), b7s18 (metapodial), b7s28 (caudal vertebra), b7s220 (incisor), b7s225 (caudal vertebra), b7s228 (metapodial), b8s3 (metapodial), b8s15 (incisor), b8s23 (upper incisor), b8s30 (metapodial), b8s51 (incisor), b8s59 (incisor), b8s65 (phalanx), b8s70 (incisor), b8s81 (metapodial), b8s82 (incisor).

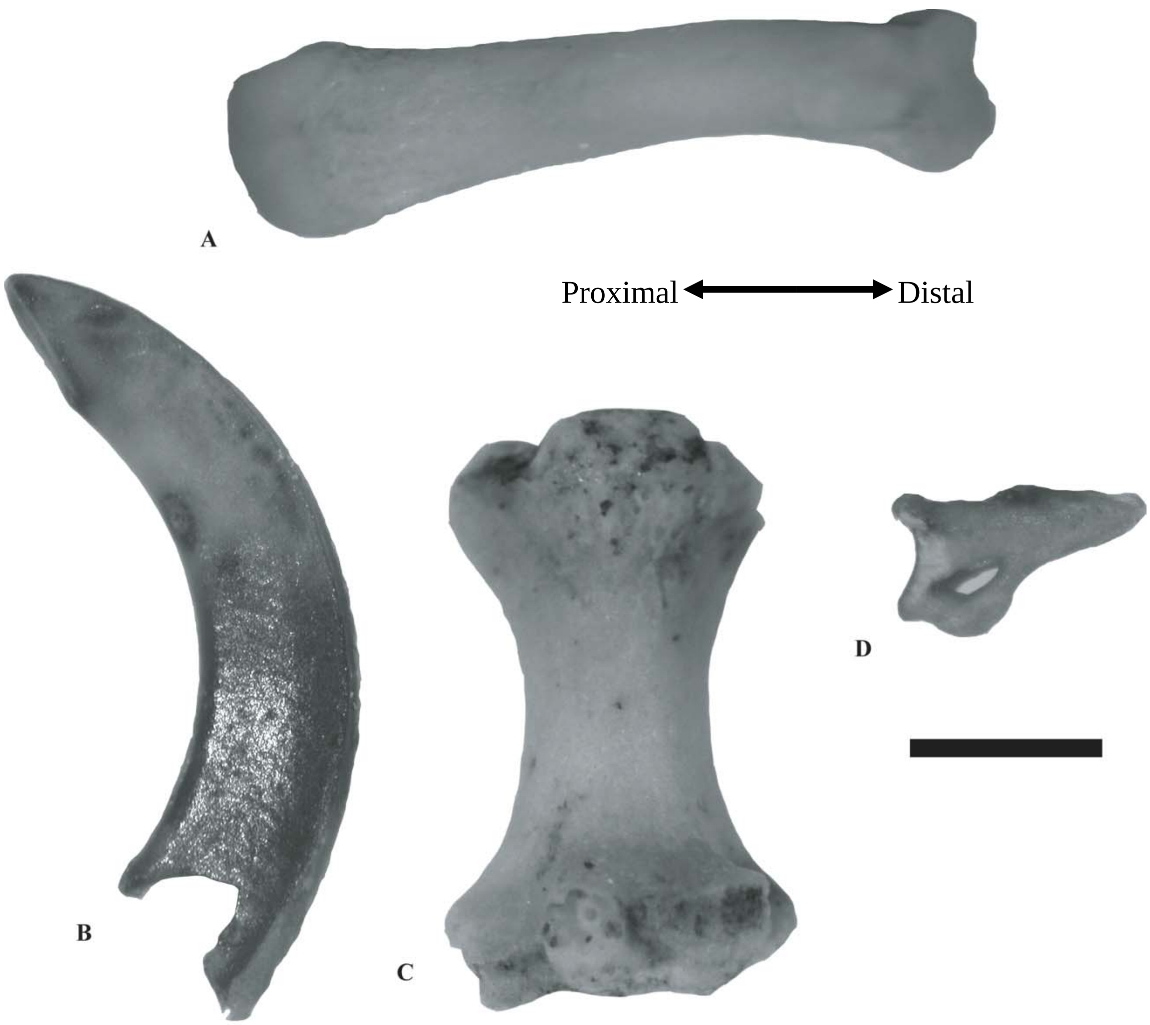

FIGURE 7. Miscellaneous mammalian skeletal elements. **A**, Metapodial (b7s18). **B**, Lateral view of incisor (b7s5). **C**, Dorsal view of caudal vertebra (b7s28). **D**, Lateral view of phalanx (b7s16). Scale bar equals 1mm. Direction applies to metapodial and phalanx

Description – Miscellaneous mammalian skeletal elements that comprise incisors, metapodials, and phalanges were found sparsely throughout the site. Incisors are long, thin, and curved teeth with a layer of enamel surrounding the teeth. Metapodials found in the site are straight bone structures and are usually small, with an average length of 2mm. The metapodials also possess a short cylindrical structure at the proximal end of the bone. Ungual phalanges possess a very slim cone like structure with an arch that grows from the distal end to the middle of the phalanges forming a slim hole. Caudal vertebrae have a short cylindrical shape with bulb like structures at both anterior and posterior end of the bone.

Discussion – All miscellaneous mammalian skeletal elements probably belong to small mammals of the site. The small size of bones, ranging from 2mm to 4mm in length could not have belonged to larger mammalian species. Therefore, none of these skeletal elements would be bones of *Lepus californicus*. The mammalian skeletal elements may have come from a shrew. However, since the incisors where not stained with red color, the incisors would have belonged to a rodent. Additionally, the skeletal elements could have come from other mammalian species found in this site such as species of *Microtus*, *Synaptomys cooperi* and/or *Reithrodontomys* sp.

Order SORICOMORPHA Gregory, 1910

Family SORICIDAE Fischer, 1814

Genus SOREX Linnaeus, 1758 or NOTIOSOREX Coues, 1877

Figure 8

Material – b1s34 (M_3), b1s45 (M_1), b1s48 (incisor), b8s52 (M_1).

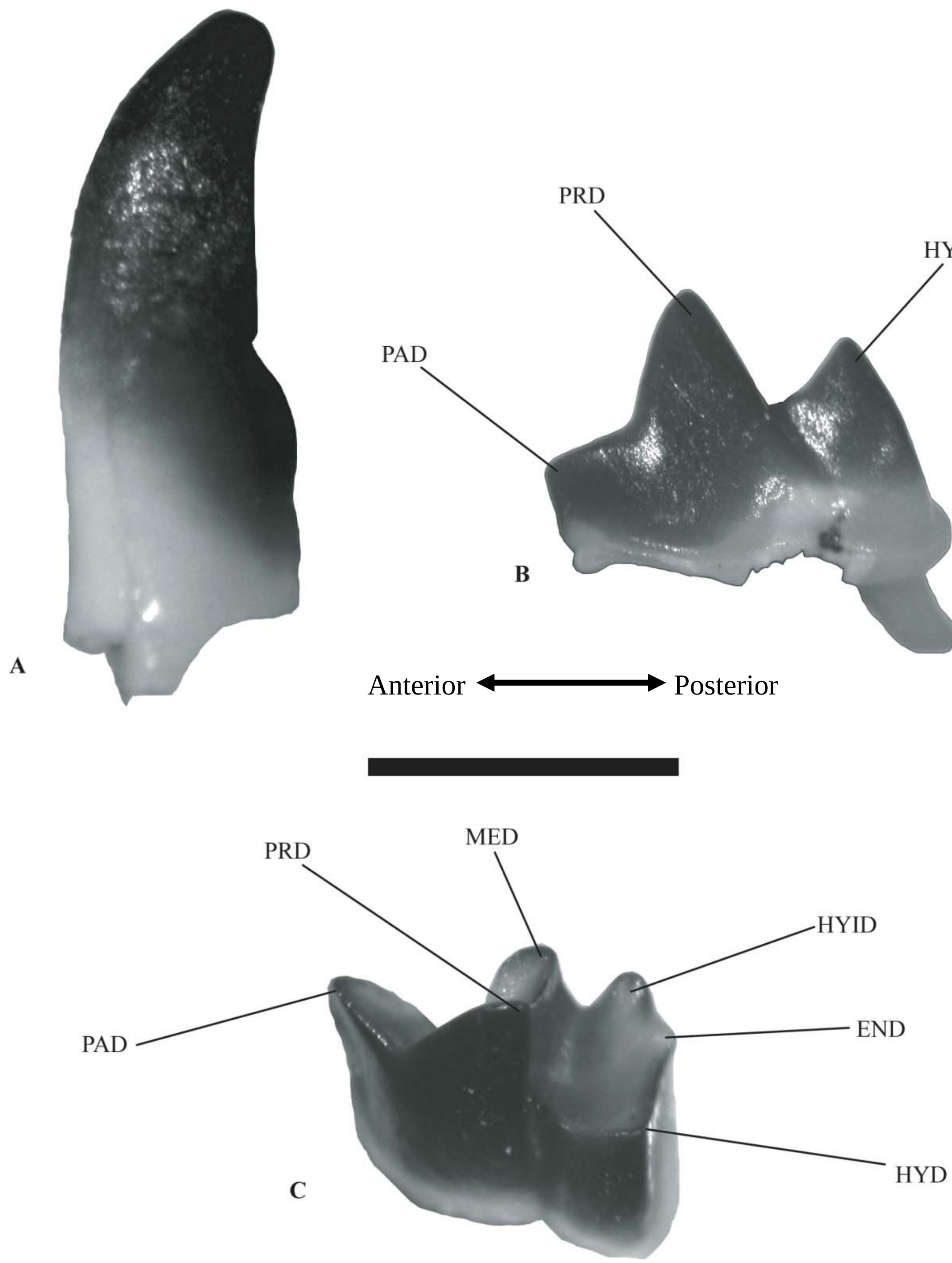

FIGURE 8. Teeth of shrews. **A**, Lateral view of *Sorex* or *Notiosorex* sp. incisor (b1s48). **B**. Lateral view of *Sorex* or *Notiosorex* sp. left lower molar (b1s46). **C**. Occlusal view of the same (b1s46). Scale bar equals 1mm. END-Entoconid; HYD-Hypoconid; HYID-Hypoconulid; MED-Metaconid; PAD-Paraconid; PRD-Protoconid.

Description – Description of the shrew teeth were based on molar morphologies. The shrew teeth are a brachydont type and low crowned. The labial side of the teeth are three-quarters red in color from the top. The tooth possesses a trigonid on the anterior section and talonid on the posterior section. The trigonid has three cusps, the paraconid, protoconid, and metaconid. The paraconid is the anterior most cusp, followed by the protoconid on the labial side and metaconid on the lingual side of tooth, located posterior to the anteroconid. The talonid has three cusps, the entoconid, hypoconid, and hypoconulid. The entoconid is located on the lingual side followed by the hypoconid located on the labial side directly posterior to the protoconid, and hypoconulid located at the posterior most end of the tooth.

Discussion – The exact identification of the genus is not done yet, due to the fact that both genera *Sorex* and *Notiosorex* share similar morphology in lower tooth morphology. Body size difference between both genera may offer indications to size differences in the teeth. However, the body size of *Notiosorex* and *Sorex* ranges across species (Hall and Kelson, 1959) and provide no real indication to size difference in teeth among genera.

Order LAGOMORPHA Brandt, 1855

Family LEPORIDAE Fischer de Waldheim, 1817

Genus LEPUS Linnaeus, 1758

Lepus californicus Gray, 1837

Figure 9

Material – b4s1 (humerus-distal portion), b4s2 (ulna-proximal portion), b7s59 (humerus-distal portion), b8s12 (lower premolar or molar), b8s21 (upper premolar or

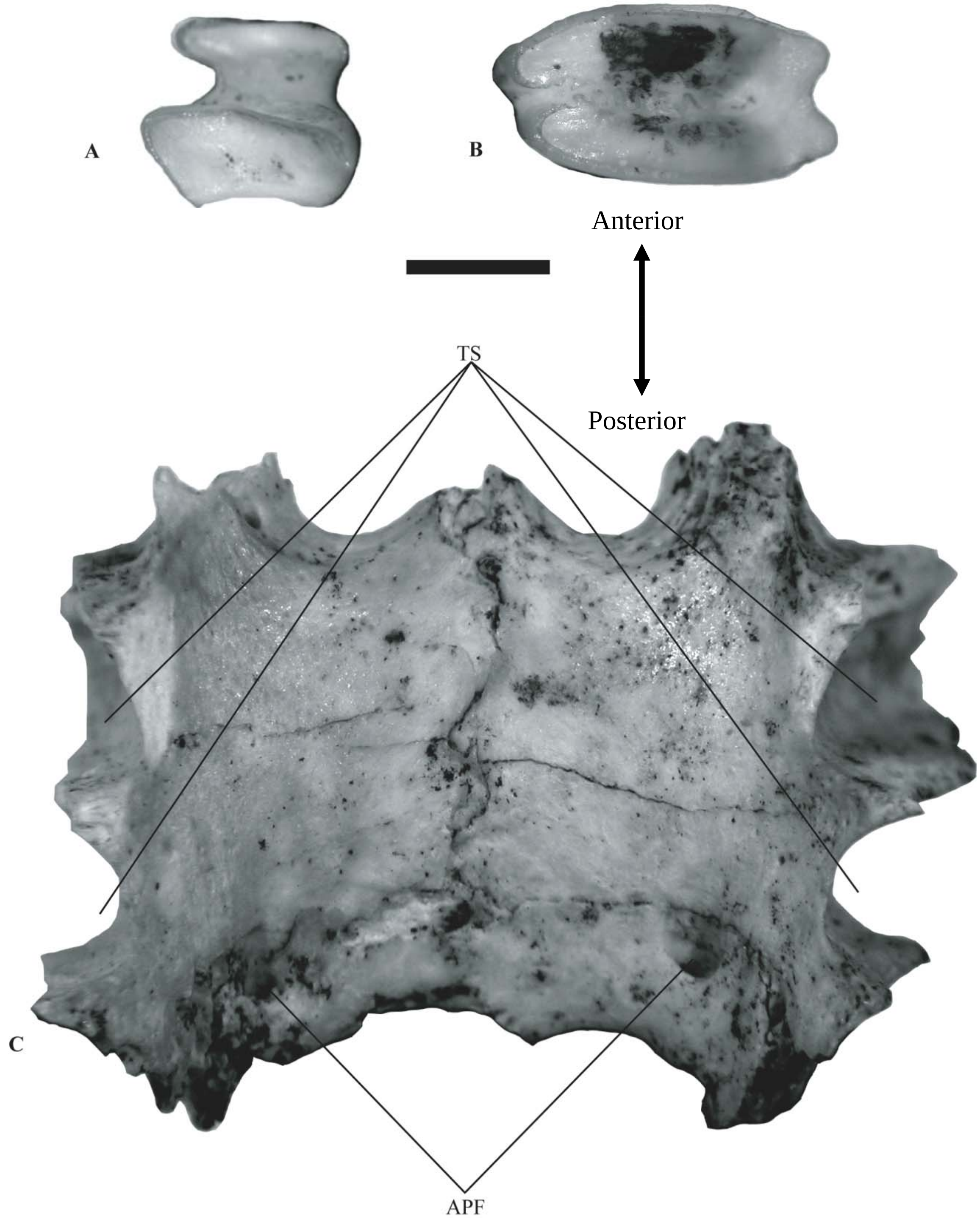

FIGURE 9. Skeletal elements of *Lepus californicus*. **A**, Occlusal view of lower premolar or molar (b8s12). **B**, Occlusal view of right upper premolar or molar (b8s46). **C**, Ventral view of palatine of *Lepus californicus* (b8s101). Scale bar equals 2mm. APF-Anterior palatine foramina; TS-tooth socket. Direction applies for all three specimens.

molar), b8s24 (upper premolar or molar), b8s30 (lower premolar or molar), b8s45 (lower premolar), b8s46 (upper premolar or molar), b8s47 (upper premolar or molar), b8s48 (lower premolar or molar), b8s49 (upper premolar or molar), b8s50 (upper premolar or molar), b8s85 (centrum), b8s86 (humerus-distal portion), b8s87 (humeral shaft), b8s88 (humeral shaft), b8s89 (centrum), b8s101 (palatine), b8s102 (humerus-distal portion), b8s103 (femur-proximal portion), b8s104 (tibia-proximal portion).

Description – Identification of the lagomorph teeth was based on premolar and molar morphologies. The lagomorph teeth is a hypsodont type (rootless), characterized by a high crown. When viewed occlusally, the teeth possesses two flat disc-like lobes, both of which are tightly constricted on the lobes' flat surfaces. When viewed antero-posteriorly, the occlusal surface of the teeth has a concave outline. The occlusal surface of teeth may be stained black with some lighter outlining on the edge of tooth. Labial side of teeth is generally smooth and about four times as high as the occlusal surface. Limb bones (femur, humerus, ulna, and tibia) comprise the largest bone elements in the site. Lagomorph vertebrae also are found at the site as acelous centra.

Discussion – *Sylvilagus* and *Lepus* have overtly similar dental features, making it very difficult to distinguish the two genera based on dental morphology alone. However, obtaining the palatine of either genus of lagomorph can make identification easier. The anterior palatine foramina of the *Lepus* palatine (Fig 9.C) are generally located more towards the edge of the posterior edge on the ventral side of the palatine (TAMU-2-82). The anterior palatine foramina of *Sylvilagus*, are located more towards the middle of the ventral side of the palatine (TAMU-2-239). In addition, the palatine of *Sylvilagus* is generally longer (TAMU-2-239) compared to the palatine of *Lepus* (TAMU-2-82).

Family CRICETIDAE Fischer, 1817

Subfamily ARVICOLINAE Gray, 1821

Genus SYNAPTOMYS Baird, 1857

Synaptomys cooperi Baird, 1857

Figure 10

Material – b5s4 (broken molar), b5s14 (broken molar), b8s11 (M^1), b8s18 (M^2), b8s43 (M^3).

Description – The rodent molar is a hypsodont type (rootless), characterized by a high crown. The occlusal view of the teeth reveals a pine cone tree-like outline. Both labial and lingual triangles are present, though lingual triangles are considerably larger and extend beyond the mid vertical line of the tooth. Reentrant angles on both sides of the molar contain cementum, which fills the top half of the molar and is smooth when viewed laterally.

Discussion – Of all rootless toothed rodents with lingual triangles exceeding beyond the mid-line of the molar, the genus *Synaptomys* is the only rodent type with cementum in the reentrant angles of molar (Semkem and Wallace, 2002). *Synaptomys cooperi* is differentiated from *Synaptomys borealis* in that *Synaptomys borealis* molars are only made of lingual triangles and completely lack labial triangles (Semkem and Wallace, 2002). Fossils of *Synaptomys cooperi* has been recovered from several other Pleistocene caves in Texas, even though the species no longer exists in the Southern regions and have been shown to be distributed to northern regions of North America (FAUNMAP working group, 1994).

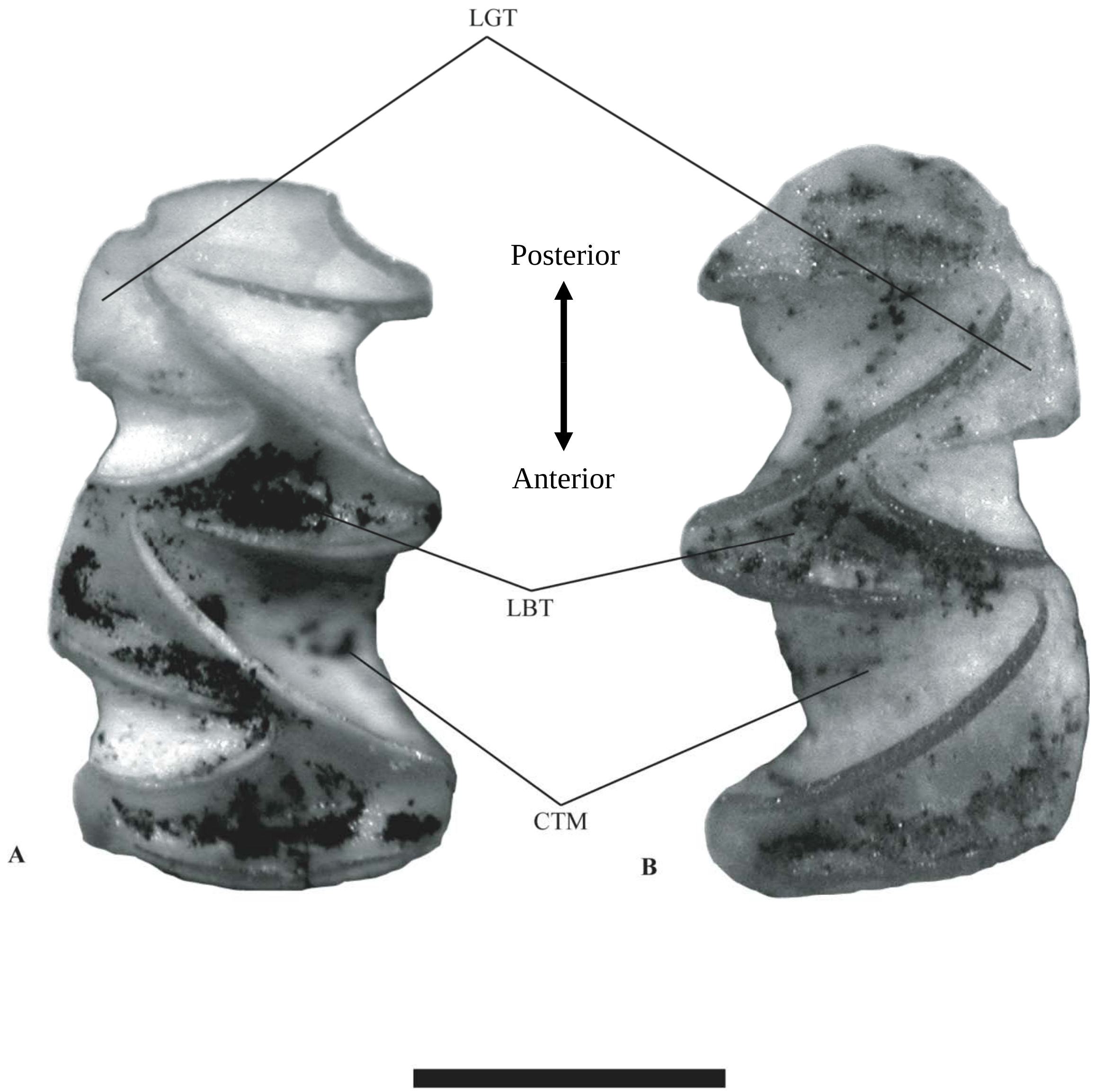

FIGURE 10. Teeth of *Synaptomys cooperi*. **A**, Occlusal view of right M^1 (b8s11). **B**, Occlusal view of left M^2 (b8s18). Scale bar equals 1mm. CMT-cementum; LBT-Labial triangle; LGT-Lingual triangle. Direction applies for both specimens.

Genus MICROTUS Schrank, 1798

Figure 11

Material – b1s32 (broken molar), b1s80 (M^1), b5s9 (M^1), b8s13 (M^1), b8s14 (M^2), b7s155 (broken molar), b8s61 (broken molar), b8s69 (broken molar).

Description – The rodent molar is a hypsodont type (rootless). Arrangement of triangles in the rodent molar begins with the anterior complex at the front of the tooth, followed by alternating triangles in zigzag formation and finally the posterior loop located at the mid-posterior base of tooth. Labial and lingual alternating triangles are generally equal in size and meets at the mid vertical line of tooth. Reentrant angles on both sides of the molar contain cementum that fills the top half of the molar and is smooth when viewed laterally. Two types of molars were obtained from the site: the 1st upper and 2nd upper molars. The 1st upper molars possess five triangles: an anterior complex, two lingual triangles, one labial triangle, and a posterior loop. The 2nd upper molar possesses four triangles: anterior complex, lingual, labial, and posterior loop.

Discussion – *Microtus* molars are easily distinguished since they have the Christmas tree outline of occlusal surface from first glance. In addition, both labial and lingual triangles are about equal in size and meet at the mid-vertical line of tooth (Semkem and Wallace, 2002:fig. 1). Identification beyond genus is, however, quite difficult due to the fact that the *Microtus* species has very little, if any, differences in tooth morphology. However, one species of vole, *Microtus pennsylvanicus,* has been eliminated as a possibility due to the fact the second molar of *Microtus pennsylvanicus* has a protruding button located at the anteroconid complex (Semkem and Wallace, 2002) that is completely missing in the second molar of this species of *Microtus*. Additionally, the triangles of this species of

Microtus do not have steep angles and have gentler curving triangles unlike the triangles of *Microtus ochrogaster* (TAMU 2-338). This species is therefore speculated to be *Microtus pinetorum* although further research is needed to confirm the identity of the species.

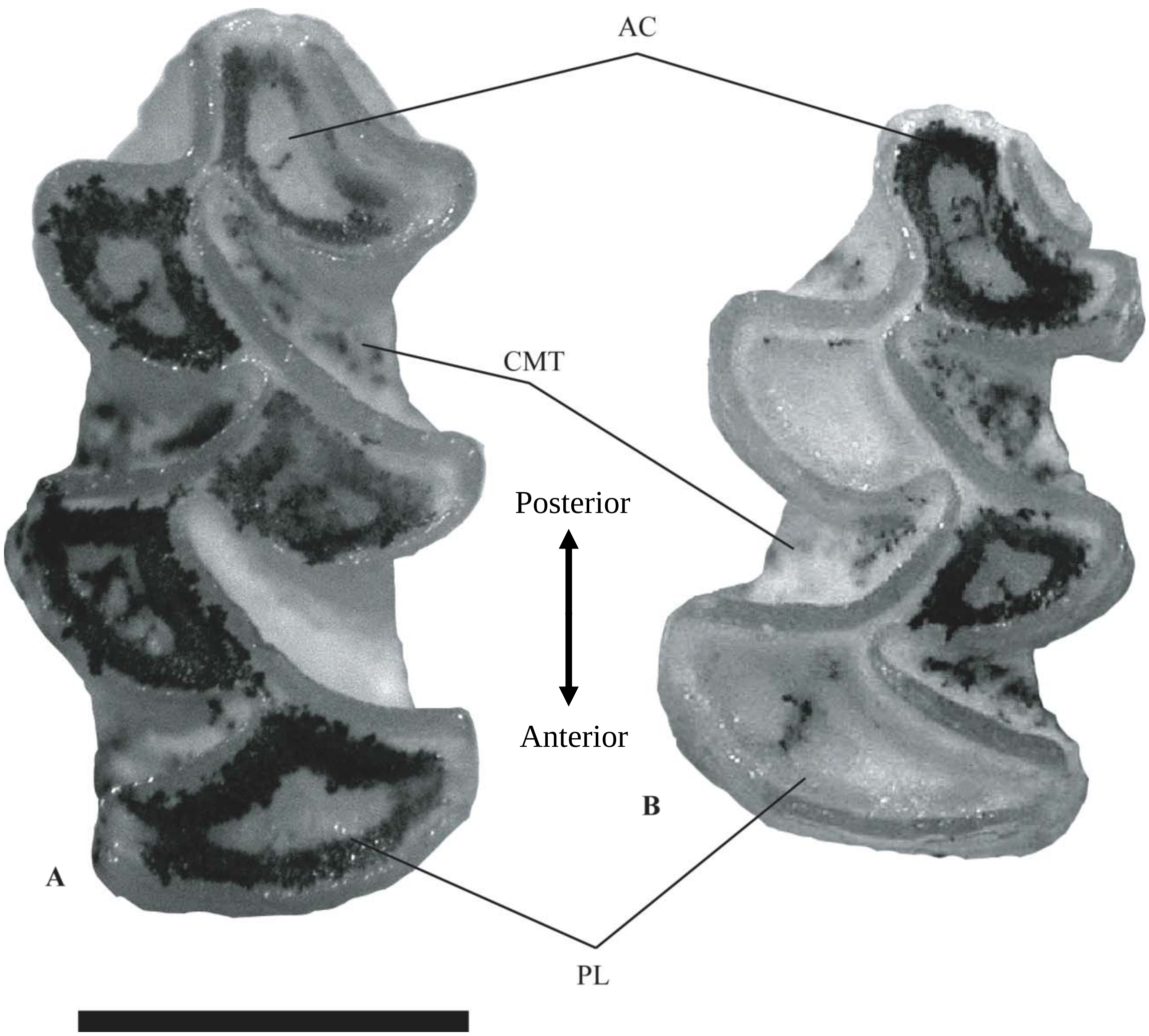

FIGURE 11. Teeth of *Microtus* sp. **A**, Occlusal view of Right M^1 (b8s13). **B**, Occlusal view of Right M^2 (b8s14). Scale bar equals 1mm. AC-Anterior complex; CMT-cementum; PL-Posterior complex. Direction applies for both specimens.

Subfamily NEOTOMINAE Merriam, 1894

Genus REITHRODONTOMYS Giglioli, 1873

Figure 12

Material – b1s43 (M^1), b5s26 (M^1), b7s1 (M_2), b7s2 (M^1), b7s3 (M_2), b7s213 (M_1), b7s227 (M_3), b8s1 (broken molar), b8s33 (M_1), b8s36 (M^1), b8s37 (M_1), b8s40 (M_1), b8s53 (M^1), b8s67 (M^3), b8s74 (M_2).

Description – The rodent tooth type being described is the lower first molar and is a brachydont tooth, characterized by a low crown. Overall shape of the 1st lower molar is an oval and has a white milky color although the space in between cusps has dark shades. The teeth are hollow and only the enamel caps are preserved. The teeth are estimated to be 1mm in length and less than 1mm in width and height. The teeth are the first lower molar of the left cheek. The 1st molars possess five cusps all of which are worn to exhibit occlusal wear to certain extent but not enough to expose the dentines. The first anterior cusp named the anteroconid is positioned more or less at the labial-lingual midpoint of the molar; anteroconid also lacks crenulations. The following posterior four cusps are arranged in alternating zigzag-like fashion and represent the major cusps in most extant mammals. The first of these four cusps is the protoconid positioned at the lingual and anterior with respect to the other major cusps. The following posterior cusp is the paraconid positioned at the labial side followed by the hypoconid on the lingual side, posterior to the protoconid. The most posterior cusp, named the metaconid, is positioned at the labial side posterior to the paraconid although a small portion of the cusp also transverse the labial-lingual mid-point. All five cusps exhibit a semi-triangular shape from wearing when viewed occlusally. The anteroconid, protoconid, paraconid and hypoconid are generally about the same size with the metaconid being slightly larger. The shape of the metaconid is also semi-triangular, but unlike the anteroconoid complex and alternating cusps, which are convex triangle in outline, the posterior loop is concave triangle in outline.

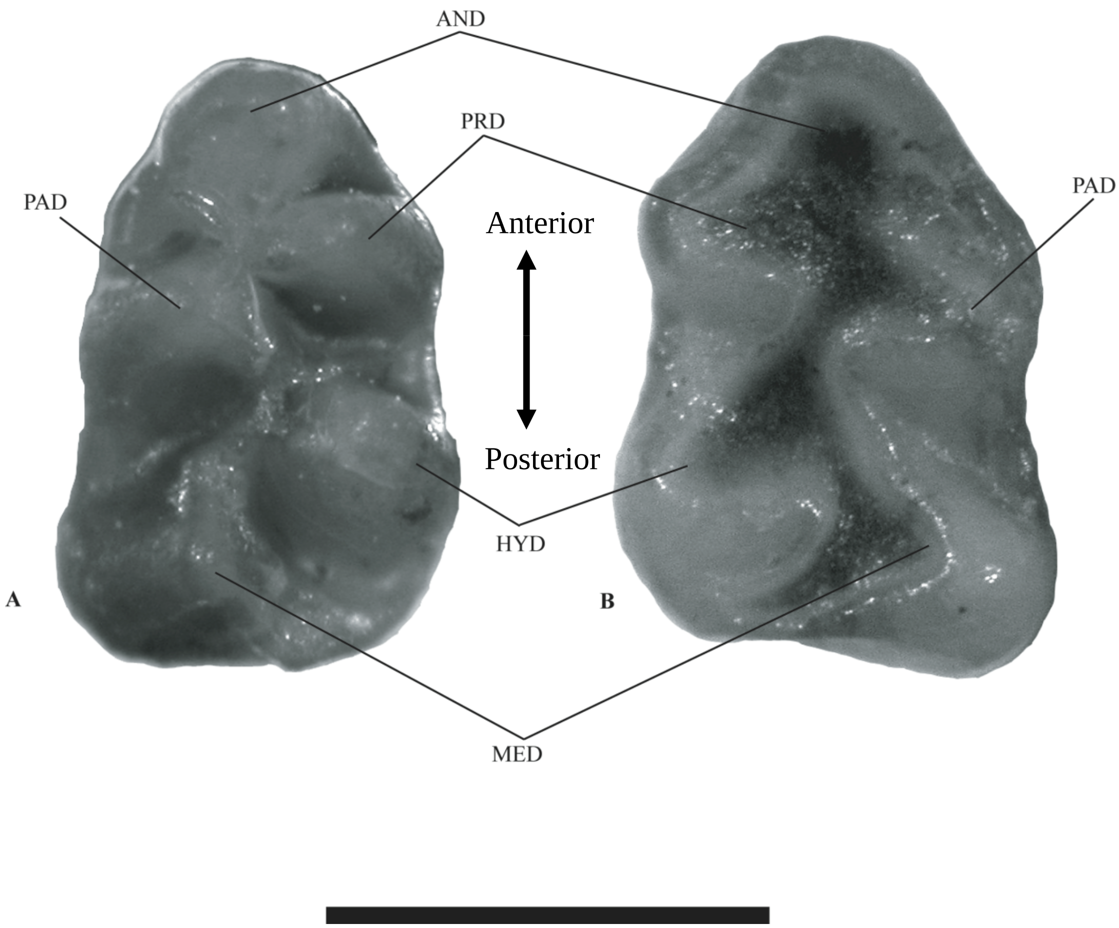

FIGURE 12. Teeth of *Reithrodontomys* sp. **A**, Occlusal view of slightly worn left M_1 (b7s2). **B**, Occlusal view of heavily worn right M_1 (b8s33). Scale bar equals 1mm. AND-Anteroconid; HYD-Hypoconid; MED-Metaconid; PAD-Paraconid; PRD-Protoconid. Direction applies for both specimens.

Discussion – *Reithrodontomys* (TAMU-2-105) molars are differentiated from *Peromyscus* (TAMU-2-314) by the arrangement of the cusps on the molar. Both *Reithrodontomys* and *Peromyscus* possess all five cusps: anteroconid, protoconid, paraconid, hypoconid, and metaconid. While arrangement of cusps of *Reithrodontomys* (TAMU-105) molar is zigzagged, the four posterior most cusps of *Peromyscus* (TAMU 2-314) are arranged in pairs. More research is required in order to tentatively identify the species of *Reithrodontomys*.

Family GEOMYIDAE Bonaparte, 1845

Genus GEOMYS Rafinesque, 1817

Figure 13

Material – b7s13 (P_4 in dentary), b8s20 (P_4).

Description – The rodent tooth is a hypsodont type (rootless) premolar with a high crown. Premolars of *Geomys*, from occlusal view, resemble the shape of an hourglass. The anterior lobe of *Geomys* lower premolar is significantly smaller in diameter compared to the posterior lobe. Both lobes of premolar are tightly constricted. One of the tooth specimens is still articulated with a piece of dentary. The dentary is located on the left lateral side of the tooth and is 5mm long and 6mm high when viewed laterally.

Discussion – Identification of genus from the Family Geomyidae is easily made from morphology of premolars. Molars from Geomyidae have only one lobe (Hall and Kelson, 1959: fig. 262) and are usually difficult to distinguish. Premolars of *Geomys* are differentiated from that of *Thomomys* in that *Geomys* premolar are more tightly constricted (Hall and Kelson, 1959: fig. 262). Premolars of *Thomomys* are less constricted (Hall and Kelson, 1959: fig. 257). While the anterior lobe of upper premolars of *Geomys* is about equal in size to the posterior lobe (Hall and Kelson, 1959: fig. 262),

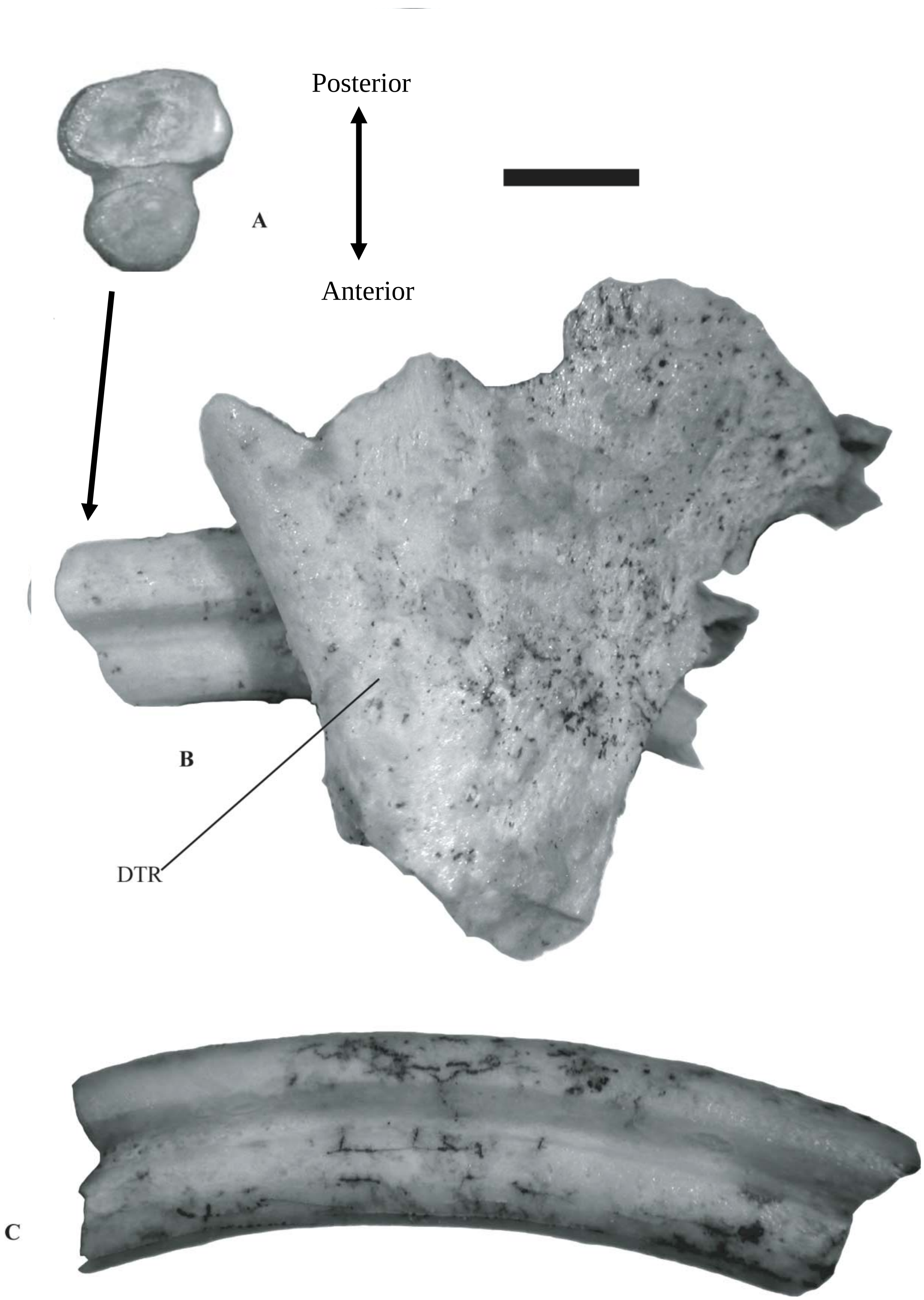

FIGURE 13. Premolars of *Geomys* sp. **A**, Occlusal view of P_4 (b7s13). **B**, Lateral view of P_4 in dentary (b7s13). C, Lateral view of P_4 (b8s20). Scale bar equals 1mm. DTR-Dentary. Direction applies for all three specimens.

the anterior lobe of upper premolars of *Thomomys* is smaller compared to the posterior lobe (Hall and Kelson, 1959: fig. 257). The anterior lobes of the 4th lower premolars of *Geomys*, however, are significantly smaller than the posterior lobes of the 4th lower premolars (Lundelius, 1992). Even though the geographic distribution of *Geomys* and *Thomomys* is much closer during the Pleistocene, the distribution of both genera remains exclusively allopatric (FAUNMAP working group, 1994).

Order CHIROPTERA BlumenBach, 1779

Figure 14

Material – b7s4 (canine).

Description – Identification is based on a single canine tooth. The tooth is cone shaped, however one side of the canine tooth is flat. Vertical linings are also present surrounding the tooth. Also, canine tooth possesses a cingulum that surrounds the circumference of the tooth near the base.

Discussion – The tooth was classified as a bat based on cingulum surrounding the entire base of canine, a feature present in bats (Hillson, 1986). There are no, if very little, literature sources with tentative identification of bat canines to lower level taxa.

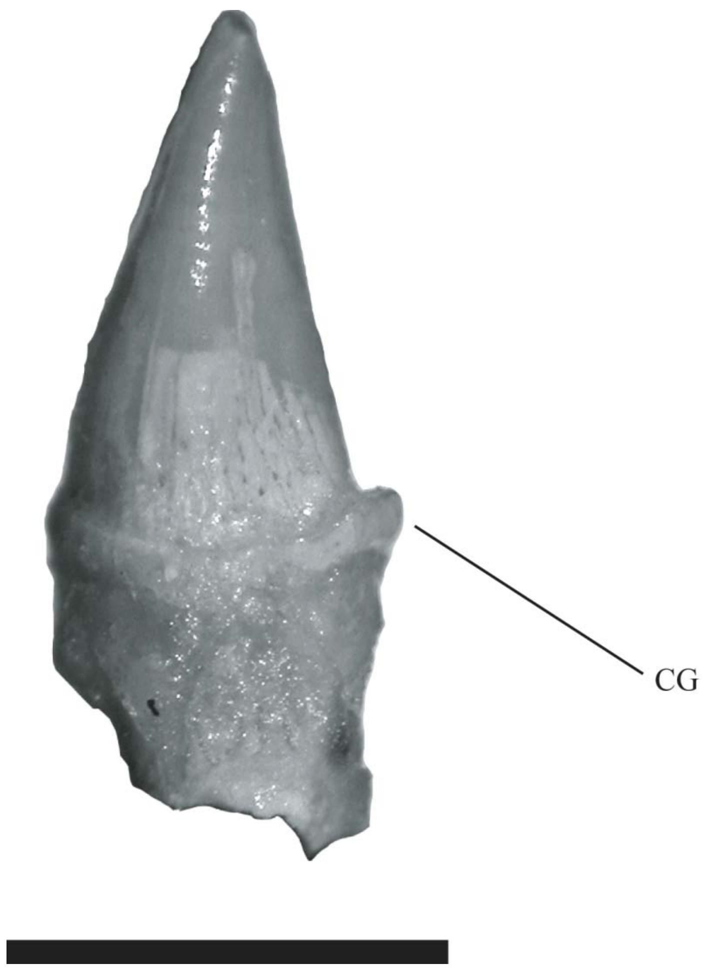

FIGURE 14. Lateral view of canine of bat (b7s4). Scale bar equals 1mm. CG-Cingulum.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Of the 11 taxa of vertebrates found in the site, there are at least 7 species of mammals, 3 species of snakes, and 1 species of fish (Table 1, Appendix 1). The only mammalian species confirmed to no longer occur in Texas is the Southern Bog Lemmings (*Synaptomys cooperi*) (FAUNMAP working group, 1994). Today, the southernmost distribution of *Synaptomys cooperi* occurs in northern Arkansas (Hall and Kelson, 1959: map 425). The species of *Microtus* found in the site may or may not have significant distribution change depending on which species of *Microtus* it is (Table 2). During the Pleistocene, three species of *Microtus* existed in Texas: *Microtus pennsylvanicus*, *Microtus ochrogaster*, and *Microtus pinetorum*; however, only one species, *Microtus pinetorum*, occurs today in Texas (FAUNMAP working group, 1994). Additionally, both species of *Microtus* that no longer occur in Texas today live in open habitats and grasslands, while *Microtus pinetorum* occurs primarily in woodland areas (Baker, 1983). *Microtus pennsylvanicus*, however, was not found in the cave site near the McKinney Falls State Park. *Microtus ochrogaster* and *Microtus pinetorum* are the only two possible species of *Microtus* that could be found in the cave site. Another taxon found in the site that may or may not have significant distribution changes are shrews, primarily shrews that belong to genera *Sorex* and *Notiosorex*. Species of *Sorex* are known to occur throughout Texas during the Pleistocene; however today there are no species of *Sorex* occurring in Texas (FAUNMAP working group, 1994). *Notiosorex*, on the other hand, occurred in Texas during the Pleistocene (FAUNMAP working group, 1994) and still do today (Hall and Kelson, 1959). All other taxa found in the site still exist in Texas. Those taxa are Harvest Mice (*Reithrodontomys* sp.), Pocket Gophers (*Geomys* sp.), Black-tailed Jackrabbit (*Lepus californicus*), and bats.

TABLE 1. Comparison of taxa across sample bags

Bag #	Snake abundance (# of skeletal elements)	Mammalian abundance (# of skeletal elements)	Snake vs. mammalian % abundance
Bag 1	*Coluber* or *Masticophis* -39 *Thamnophis* or *Nerodia* -7 *Elaphe bairdi* -1 Colubridae elements -41	*Reithrodontomys* -1 *Sorex* or *Notiosorex* -3 *Microtus* sp. -1 Mammalian elements -3	Snake – 92.6% Mammalian – 7.4%
Bag 2	*Coluber* or *Masticophis* -28 *Thamnophis* or *Nerodia* -2	0	Snake – 100% Mammalian – 0%
Bag 3	*Elaphe bairdi* - 1	0	Snake – 100% Mammalian – 0%
Bag 4	*Coluber* or *Masticophis* -5 *Thamnophis* or *Nerodia* -5 Colubridae elements -3	*Lepus californicus* -2 Mammalian elements -1	Snake – 81.3% Mammalian – 18.7%
Bag 5	*Coluber* or *Masticophis* -14 *Thamnophis* or *Nerodia* -20 Colubridae elements -11	*Synaptomys cooperi* -2 *Reithrodontomys* sp. -1 *Microtus* sp. -1	Snake – 91.8% Mammalian – 8.2%
Bag 6	Colubridae elements -4	Mammalian elements -3	Snake – 57.1% Mammalian – 42.9%
Bag 7	*Coluber* or *Masticophis* -61 *Thamnophis* or *Nerodia* -29 *Elaphe bairdi* -1 Colubridae elements -99	*Reithrodontomys* -4 *Microtus* -1 *Lepus californicus* -1 *Geomys* -1 Bat -1 Rodent elements -6	Snake – 93.1% Mammalian – 6.9%
Bag 8	*Elaphe bairdi* -3 *Coluber* or *Masticophis* -18 *Thamnophis* or *Nerodia* -10 Colubridae elements -20	*Reithrodontomys* sp. -8 *Microtus* sp. -4 *Synaptomys cooperi* -4 *Lepus californicus* -19 *Sorex* or *Notiosorex* -1 *Geomys* -1 Rodent elements -10	Snake – 45.7% Mammalian – 54.3%

The identities of the three species of snakes found at the site are *Coluber constrictor* (racers) or *Masticophis* sp. (whiptail snakes), *Thamnophis* sp. (garter snakes) or *Nerodia* sp. (water snake), and *Elaphe bairdi* (Baird's rat snake). *Coluber constrictor* is the only species of *Coluber* found in North America during both Pleistocene (Holman, 2000) and Holocene (Tennant, 1998); however, there is more than one species of *Masticophis* occurring in Texas during the Pleistocene (Holman, 2000) and present (Werler and Dixon, 2000). Since it is extremely difficult to distinguish between species of *Coluber* or *Masticophis* (Parmley, 1986), either one of the two species or both species may be present at the site. If both species are present, then the site will have at least four species of snakes. There also were difficulties in attempting to distinguish vertebrae of *Thamnophis* and *Nerodia* in my site due to the fragmentary nature of the vertebrae. If both species of *Nerodia* and *Thamnophis* occur in the site, then the site will have at least five species of snake depending on whether or not both *Coluber* and *Masticophis* are present.

TABLE 2. Comparison of Pleistocene localities.

	Laubach Cave	Avenue Local Fauna
Extinct taxa	*Mammuthus* sp. *Megalonyx jeffersoni* *Homotherium serum*	*Mammuthus* sp. *Mammut americanum* *Equus* sp. *Glossotherium harlani*
Taxa shared with cave near McKinney Falls State park	*Microtus* sp. *Geomys* sp. *Lepus californicus* Bat	*Microtus* sp. *Synaptomys cooperi* *Geomys* sp.

This site is unique compared to other Texas Pleistocene cave site for the large amount of snake skeletal elements (84.23%) compared to the mammalian skeletal elements (15.77%) obtained (Table 1). The distribution of snake skeletal elements was generally even across the site indicating a uniform abundance. Additionally, all five species of snakes, *Coluber constrictor*, *Masticophis* sp., *Nerodia* sp., *Thamnophis* sp., and *Elaphe bairdi*, obtained at the site form hibernacula today (Werler and Dixon, 2000). Since three or more species of snakes were found at the site, it may indicate the presence of a multispecies snake hibernacula during the Pleistocene. Currently, the southernmost extension of multispecies snake hibernacula ever found was in Missouri (Sexton and Hunt, 1980), Oklahoma (Fitch, 1960), and Utah (Hirth, 1966), and it was implied that no multispecies snake hibernacula occur today in Texas (Werler and Dixon, 2000). Until this cave site was discovered no fossil multispecies snake hibernacula has ever been found in the world. The large number of snake skeletal elements, uniform abundance, and the presence of three or more species of snakes makes this cave site a strong candidate to be the world's first fossil multispecies snake hibernacula ever discovered.

Abundance of skeletal elements and types of species varies across all eight bags obtained from the site. As shown in the Table 1, all snake species, except *Elaphe bairdi*, were found in large numbers in proportions to the mammalian skeletal elements. No mammals were found in bags 2 and 3. Additionally mammalian species are not found consistently across the site. Shrews have only been found in bags 1 and 8 while *Synaptomys cooperi* has only been found in bags 5 and 8. *Reithrodontomys* sp. and *Lepus californicus* had a larger and wider abundance relative to other mammalian species across the site. Interesting to note is that bag 8 is the only collection with more mammalian elements than snake elements. Bag 8 is also the only bag with all species of snakes and nearly all species of mammals found in the site. Still, snakes tend to have larger number of skeletal elements in all other bags and represent the most abundant animals in the cave site.

The mammalian fauna obtained from the site is consistent with a Pleistocene age deposit. The confirmation of the Pleistocene age of the site is based on comparative mammalian fauna to other Texas Pleistocene localities. Since fossils of *Synaptomys cooperi* and *Microtus* sp. were found in the cave site, the cave deposit is Pleistocene in age. The cave fauna exhibits two of the three attributes found across Texas Pleistocene cave sites: extant species with significant distribution change and species still locally extant in Texas. The other attribute was not exhibited in this site due to the fact that all taxa found in the site are extant. All mammalian species identified in this site can also be found across other Pleistocene cave sites in Texas (Table 2). However, most localities in Texas also exhibit species that have undergone complete extinction at the end of the Pleistocene. A cave site known as Laubach Cave contains extinct species such as mammoths (*Mammuthus* sp.), Jefferson's ground sloth (*Megalonyx jeffersoni*), and saber-toothed cats (*Homotherium serum*) (Lundelius, 1985). Taxa shared among this cave and Laubach Cave are pocket gophers (*Geomys* sp.), voles (*Microtus* sp.), black-tailed jackrabbits (*Lepus californicus*), and two species of bats: little brown bats (*Myotis* sp.), and Mexican-free-tail bats (*Tadarida brasiliensis*) (Lundelius, 1985). Another type of Texas Pleistocene locality are alluvial deposits such as the Local Avenue Fauna discovered in Austin (Lundelius, 1992). This site also contains taxa that are now extinct along extant taxa that are also found in the cave near the McKinney Falls State Park

(Lundelius, 1992). Among the extinct taxon found in Local Avenue Fauna are mammoths (*Mammuthus* sp.), American mastodon (*Mammut americanum*), horses (*Equus* sp.), and Harlan's ground sloth (*Glossotherium harlani*) (Lundelius, 1992). Extant taxa shared among Avenue Local Fauna and the cave site near McKinney Falls are voles (*Microtus* sp), southern bog lemming (*Synaptomys cooperi*), and pocket gophers (*Geomys* sp.). Therefore, of all taxa of vertebrates collected from Texas Pleistocene localities, mammals are most indicative of change in time from the Pleistocene to the Holocene Epoch. Snakes obtained from this cave site, however, do not exhibit any change in distribution (Holman, 2000) and this indicates that snake do not respond geographically to climate change.

An important change that occurred between the Pleistocene and Holocene Epochs is the change in the glacial cycle that ended 11.5 thousand years ago (Gibbard and Kolfschoten, 2004). As mentioned in the introduction, the last glacial period, the Wisconsin glacial, ended 11.5 thousand years ago and therefore began the current interglacial, the Holocene interglacial (Gibbard and Kolfschoten, 2004). The change from a glacial to interglacial period resulted in large environmental changes throughout North America (McDonald, 1984). Many large mammals went extinct right about the same time as the Wisconsin Glacial drew to an end (Gutherie, 1984). It is tempting to say that these creatures have gone extinct due to changing climate, however other factors could also have resulted in the extinction of large mammalian species such as overhunting by humans (Martin, 1984) or changing vegetation as a result of changing climate (Guthrie, 1984). Other creatures that were able to cope with such change in climate either shifted in distribution northwards or remained in Texas (FAUNMAP working group, 1996). Such taxa with spatial distribution change would reveal their tolerance limit and the extent to which a changing environment may influence their distribution (FAUNMAP working group, 1996). One example of such difference in adaptability is the spatial distribution changes of some species of *Microtus* relative to other species of *Microtus*. As mentioned earlier, both species of *Microtus* that occur in open habitats have now shifted northwards, while *Microtus pinetorum*, occurring in woodland areas, continues to remain in Texas (FAUNMAP working group, 1994). This brings up a question of possible changes in vegetation that may have occurred after the end of the Pleistocene that may account for the difference in the *Microtus* distribution change. However, more research is required in order to confirm the changing vegetation in Texas as evidence of the difference in distribution of species of *Microtus*. Other taxa with less complex changes in geographic distribution are *Synaptomys cooperi* and all species of *Sorex*; two taxa that are no longer found in Texas and occur in north regions of North America (Graham, 1997) as a result of climate change.

This change in climate from the Pleistocene to the Holocene could not only caused change in spatial distribution of some mammals, but also a potential change in behavior among reptiles, in this case, snakes. As mentioned in the introduction, no multispecies snake hibernacula occur today in Texas (Werler and Dixon, 2000) and the southern-most extension of multispecies snake hibernacula occur in Missouri (Sexton and Hunt, 1980), Oklahoma (Fitch, 1960) and Utah (Hirth, 1966). In Texas, where winters are milder and shorter compared to northern regions, snakes will tend to hibernate alone and rarely in groups (Ditmars, 1939). In northern regions however, snakes will sometimes hibernate in large groups often times with several other species of snakes; such snakes include but are not limited to, racers, garter, rat, whiptail and copperhead snakes (Werler and Dixon, 2000). As shown from a hibernaculum in Oklahoma, copperhead snakes (*Scytalus cupreus*) have been found hibernating with other snakes such as *Masticophis flagellum* and *Agkistrodon piscivorus* (Fitch, 1960). In colder environments, hibernacula are part of an important behavior in snake species, survival. Since Texas was thought to be as cold as some northern regions during the Pleistocene, it would not be unusual to find multispecies hibernacula during the Pleistocene in Texas. The shift from a colder to a warmer climate may cause species of snakes to form fewer or no multispecies hibernacula due to the fact that winters are now milder and snakes are no longer compelled to hibernate with other species of snakes. Although this makes sense, it is only a hypothesis and more research is required to fully understand the relationship between multispecies snake hibernacula and climate change. The presence of fossil mammals and snakes in a single site also is not unusual. Since this was a cave, some mammal species may wander into the cave for shelter and ended up dying there. Some of the mammals could also be brought into the cave by predators or even a flooding event since there is a creek nearby that could potentially flooded. However, it is hard to test how the mammalian species got into the cave and most ideas are purely speculative.

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APPENDIX 1

1. 1	Colubridae	Caudal vertebra
1. 2	Colubridae	Caudal vertebra
1. 3	Vertebrata	Unknown fragment
1. 4	Mammalia	Metapodial
1. 5	Colubridae	Tooth
1. 6	Colubridae	Tooth
1. 7	Colubridae	Caudal vertebra
1. 8	*Thamnophis* or *Nerodia*	Thoracic vertebra
1. 9	Colubridae	Tooth
1. 10	Colubridae	Tooth bearing skull bone
1. 11	Colubridae	Caudal vertebra
1. 12	Colubridae	Tooth
1. 13	*Thamnophis* or *Nerodia*	Thoracic vertebra
1. 14	Colubridae	Caudal vertebra
1. 15	Colubridae	Tooth
1. 16	Colubridae	Tooth
1. 17	Colubridae	Caudal vertebra
1. 18	Colubridae	Tooth
1. 19	Colubridae	Caudal vertebra
1. 20	Colubridae	Caudal vertebra
1. 21	Colubridae	Tooth
1. 22	Colubridae	Tooth
1. 23	Colubridae	Tooth bearing skull bone
1. 24	Vertebrata	Unknown fragment
1. 25	Colubridae	Tooth
1. 26	Vertebrata	Unknown fragment
1. 27	Colubridae	Tooth
1. 28	Colubridae	Tooth
1. 29	Colubridae	Tooth bearing skull bone
1. 30	Colubridae	Tooth
1. 31	Colubridae	Tooth
1. 32	*Microtus* sp.	Broken molar
1. 33	*Sorex* or *Notiosorex*	1st lower molar
1. 34	*Sorex* or *Notiosorex*	3rd lower molar
1. 35	Colubridae	Tooth
1. 36	Colubridae	Tooth bearing skull bone
1. 37	Colubridae	Caudal vertebra
1. 38	Colubridae	Tooth

1. 39	Colubridae	Caudal vertebra
1. 40	Colubridae	Caudal vertebra
1. 41	Colubridae	Tooth
1. 42	Colubridae	Tooth
1. 43	*Reithrodontomys* sp.	1st upper molar
1. 44	*Coluber* or *Masticophis*	Vertebra
1. 45	Sorex or Notiosorex	1st lower molar
1. 46	*Coluber* or *Masticophis*	Vertebra
1. 47	Colubridae	Tooth
1. 48	*Sorex* or *Notiosorex*	Incisor
1. 49	Colubridae	Tooth
1. 50	Colubridae	Caudal vertebra
1. 51	*Thamnophis* or *Nerodia*	Vertebra
1. 52	*Coluber* or *Masticophis*	Vertebra
1. 53	*Coluber* or *Masticophis*	Vertebra
1. 54	*Coluber* or *Masticophis*	Vertebra
1. 55	*Coluber* or *Masticophis*	Vertebra
1. 56	*Coluber* or *Masticophis*	Vertebra
1. 57	*Coluber* or *Masticophis*	Vertebra
1. 58	*Coluber* or *Masticophis*	Vertebra
1. 59	*Coluber* or *Masticophis*	Vertebra
1. 60	*Thamnophis* or *Nerodia*	Vertebra
1. 61	*Coluber* or *Masticophis*	Vertebra
1. 62	*Coluber* or *Masticophis*	Vertebra
1. 63	*Coluber* or *Masticophis*	Vertebra
1 .64	*Thamnophis* or *Nerodia*	Vertebra
1 .65	Colubridae	Caudal vertebra
1. 66	*Coluber* or *Masticophis*	Vertebra
1. 67	*Coluber* or *Masticophis*	Vertebra
1 .68	*Coluber* or *Masticophis*	Vertebra
1. 69	*Thamnophis* or *Nerodia*	Vertebra
1 .70	*Coluber* or *Masticophis*	Vertebra
1. 71	*Coluber* or *Masticophis*	Vertebra
1 .72	*Coluber* or *Masticophis*	Vertebra
1. 73	*Coluber* or *Masticophis*	Vertebra
1. 74	*Coluber* or *Masticophis*	Vertebra
1. 75	*Coluber* or *Masticophis*	Vertebra
1. 76	*Thamnophis* or *Nerodia*	Vertebra
1. 77	*Coluber* or *Masticophis*	Vertebra
1. 78	*Coluber* or *Masticophis*	Vertebra

1. 79	*Coluber* or *Masticophis*	Vertebra
1. 80	*Microtus* sp.	Broken molar
1. 81	*Coluber* or *Masticophis*	Vertebra
1. 82	*Coluber* or *Masticophis*	Vertebra
1. 83	Colubridae	Caudal vertebra
1. 84	Colubridae	Rib
1. 85	*Coluber* or *Masticophis*	Vertebra
1. 86	*Coluber* or *Masticophis*	Vertebra
1. 87	*Coluber* or *Masticophis*	Vertebra
1. 88	*Coluber* or *Masticophis*	Vertebra
1. 89	Colubridae	Rib
1. 90	*Coluber* or *Masticophis*	Vertebra
1. 91	Colubridae	Caudal vertebra
1. 92	*Coluber* or *Masticophis*	Vertebra
1. 93	*Coluber* or *Masticophis*	Vertebra
1. 94	*Coluber* or *Masticophis*	Vertebra
1. 95	*Coluber* or *Masticophis*	Vertebra
1. 96	*Elaphe bairdi*	Vertebra
1. 97	*Coluber* or *Masticophis*	Vertebra
1. 98	*Coluber* or *Masticophis*	Vertebra
1. 99	*Coluber* or *Masticophis*	Vertebra
2. 1	*Coluber* or *Masticophis*	Vertebra
2. 2	*Coluber* or *Masticophis*	Vertebra
2. 3	*Coluber* or *Masticophis*	Vertebra
2. 4	*Coluber* or *Masticophis*	Vertebra
2. 5	*Coluber* or *Masticophis*	Vertebra
2. 6	*Coluber* or *Masticophis*	Vertebra
2. 7	*Coluber* or *Masticophis*	Vertebra
2. 8	*Coluber* or *Masticophis*	Vertebra
2. 9	*Coluber* or *Masticophis*	Vertebra
2. 10	*Coluber* or *Masticophis*	Vertebra
2. 11	*Coluber* or *Masticophis*	Vertebra
2. 12	*Coluber* or Masticophis	Vertebra
2. 13	*Coluber* or *Masticophis*	Vertebra
2. 14	*Coluber* or *Masticophis*	Vertebra
2. 15	*Coluber* or *Masticophis*	Vertebra
2. 16	*Coluber* or *Masticophis*	Vertebra
2. 17	*Coluber* or *Masticophis*	Vertebra
2. 18	*Coluber* or *Masticophis*	Vertebra
2. 19	*Coluber* or *Masticophis*	Vertebra

2. 20	*Coluber* or *Masticophis*	Vertebra
2. 21	*Coluber* or *Masticophis*	Vertebra
2. 22	*Coluber* or *Masticophis*	Vertebra
2. 23	*Coluber* or *Masticophis*	Vertebra
2. 24	*Thamnophis* or *Nerodia*	2 Vertebrae (articulated)
2. 25	*Coluber* or *Masticophis*	Vertebra
2. 26	*Coluber* or *Masticophis*	Vertebra
2. 27	*Coluber* or *Masticophis*	Vertebra
2. 28	*Coluber* or *Masticophis*	Vertebra
2. 29	*Coluber* or *Masticophis*	Vertebra
3. 1	*Elaphe bairdi*	Vertebra
4. 1	*Lepus californicus*	Humerus-distal portion
4. 2	*Lepus californicus*	Ulna-proximal portion
4. 3	*Coluber* or *Masticophis*	Vertebra
4. 4	*Coluber* or *Masticophis*	Vertebra
4. 5	*Coluber* or *Masticophis*	Vertebra
4. 6	*Coluber* or *Masticophis*	Vertebra
4. 7	*Coluber* or *Masticophis*	Vertebra
4. 8	Vertebrata	Unknown fragment
4. 9	Mammalia	Metapodial
4. 10	Colubridae	Tooth
4. 11	Vertebrata	Unknown fragment
4. 12	Colubridae	Tooth
4. 13	*Thamnophis* or *Nerodia*	Vertebra
4. 14	*Thamnophis* or *Nerodia*	Vertebra
4. 15	Colubridae	Rib
4. 16	*Thamnophis* or *Nerodia*	Vertebra
4. 17	*Thamnophis* or *Nerodia*	Vertebra
4. 18	*Thamnophis* or *Nerodia*	Vertebra
5. 2	Colubridae	Tooth
5. 3	*Thamnophis* or *Nerodia*	Vertebra
5. 4	*Synaptomys cooperi*	Broken molar
5. 5	*Coluber* or *Masticophis*	Vertebra
5. 6	*Thamnophis* or *Nerodia*	Vertebra
5. 7	*Thamnophis* or *Nerodia*	Vertebra
5. 8	Colubridae	Vertebra
5. 9	*Microtus* sp.	1st upper molar
5. 10	Colubridae	Caudal vertebra
5. 11	*Coluber* or *Masticophis*	Vertebra

5. 12	*Thamnophis* or *Nerodia*	Vertebra
5. 13	*Thamnophis* or *Nerodia*	Vertebra
5. 14	*Synaptomys cooperi*	Broken molar
5. 15	Colubridae	Tooth bearing skull bone
5. 16	*Thamnophis* or *Nerodia*	Vertebra
5. 17	*Thamnophis* or *Nerodia*	Vertebra
5. 18	Colubridae	Caudal vertebra
5. 19	*Coluber* or *Masticophis*	Vertebra
5. 20	*Coluber* or *Masticophis*	Vertebra
5. 21	*Coluber* or *Masticophis*	Vertebra
5. 22	Colubridae	Caudal vertebra
5. 23	Colubridae	Tooth bearing skull bone
5. 24	Colubridae	Tooth bearing skull bone
5. 25	*Coluber* or *Masticophis*	Vertebra
5. 26	*Reithrodontomys* sp.	1st upper molar
5. 27	*Thamnophis* or *Nerodia*	Vertebra
5. 28	*Coluber or Masticophis*	Vertebra
5. 29	*Coluber* or *Masticophis*	Vertebra
5. 30	*Coluber* or *Masticophis*	Vertebra
5. 31	*Coluber* or *Masticophis*	Vertebra
5. 32	Colubridae	Rib
5. 33	*Thamnophis* or *Nerodia*	Vertebra
5. 34	*Coluber* or *Masticophis*	Vertebra
5. 35	*Thamnophis* or *Nerodia*	Vertebra
5. 36	*Thamnophis* or *Nerodia*	Vertebra
5. 37	*Thamnophis* or *Nerodia*	Vertebra
5. 38	*Thamnophis* or *Nerodia*	Vertebra
5. 39	*Thamnophis* or *Nerodia*	Vertebra
5. 40	*Coluber* or *Masticophis*	Vertebra
5. 41	*Thamnophis* or *Nerodia*	Vertebra
5. 42	*Thamnophis* or *Nerodia*	Vertebra
5. 43	*Thamnophis* or *Nerodia*	Vertebra
5. 44	Colubridae	Vertebra
5. 45	*Coluber* or *Masticophis*	Vertebra
5. 46	Colubridae	Vertebra
5. 47	*Coluber* or *Masticophis*	Vertebra
5. 48	*Thamnophis* or *Nerodia*	Vertebra
5. 49	*Thamnophis* or *Nerodia*	Vertebra
6. 1	Colubridae	Caudal vertebra
6. 2	Colubridae	Tooth

6. 3	Colubridae	Tooth
6. 4	Colubridae	Tooth
6. 5	Mammalia	Metapodial
6. 6	Mammalia	Caudal vertebra
6. 7	Mammalia	Metapodial
7. 1	*Reithrodontomys* sp.	2nd lower molar
7. 2	*Reithrodontomys* sp.	1st lower molar
7. 3	*Reithrodontomys* sp.	2nd lower molar
7. 4	Bat	Canine
7. 5	Mammalia	Upper incisor
7. 6	Colubridae	Tooth
7. 7	Colubridae	Tooth
7. 8	Colubridae	Tooth
7. 9	Colubridae	Tooth
7. 10	Colubridae	Tooth bearing skull bone
7. 11	Colubridae	Tooth bearing skull bone
7. 12	Colubridae	Tooth bearing skull bone
7. 13	*Geomys* sp.	4th lower premolar in dentary
7. 14	Colubridae	Tooth bearing skull bone
7. 15	Colubridae	Tooth bearing skull bone
7. 16	Mammalian	Ungual phalanx
7. 17	Colubridae	Caudal most vertebra
7. 18	Mammalian	Metapodial
7. 19	Vertebrata	Unknown fragment
7. 20	Vertebrata	Unknown fragment
7. 21	Colubridae	Rib
7. 22	Vertebrata	Unknown fragment
7. 23	Vertebrata	Unknown fragment
7. 24	Colubridae	Rib
7. 25	Vertebrata	Unknown fragment
7. 26	Colubridae	Condyle
7. 27	*Thamnophis* or *Nerodia*	Vertebra
7. 28	Mammalia	Caudal vertebra
7. 29	*Coluber* or *Masticophis*	Vertebra
7. 30	*Thamnophis* or *Nerodia*	Vertebra
7. 31	*Coluber* or *Masticophis*	Vertebra
7. 32	*Thamnophis* or *Nerodia*	Vertebra
7. 33	*Coluber* or *Masticophis*	Vertebra
7. 34	*Thamnophis* or *Nerodia*	Vertebra
7. 35	Colubridae	Caudal vertebra

7. 36	*Thamnophis* or *Nerodia*	Vertebra
7. 37	*Thamnophis* or *Nerodia*	Vertebra
7. 38	*Coluber* or *Masticophis*	Vertebra
7. 39	*Thamnophis* or *Nerodia*	Vertebra
7. 40	*Thamnophis* or *Nerodia*	Vertebra
7. 41	*Coluber* or *Masticophis*	Vertebra
7. 42	*Coluber* or *Masticophis*	Vertebra
7. 43	*Thamnophis* or *Nerodia*	Vertebra
7. 44	*Coluber* or *Masticophis*	Vertebra
7. 45	*Coluber* or *Masticophis*	Vertebra
7. 46	*Elaphe bairdi*	Vertebra
7. 47	*Coluber* or *Masticophis*	Vertebra
7. 48	*Coluber* or *Masticophis*	Vertebra
7. 49	*Coluber* or *Masticophis*	Vertebra
7. 50	*Coluber or Masticophis*	Vertebra
7. 51	*Coluber* or *Masticophis*	Vertebra
7. 52	*Coluber* or *Masticophis*	Vertebra
7. 53	*Coluber* or *Masticophis*	Vertebra
7. 54	Colubridae	Caudal vertebra
7. 55	*Thamnophis* or *Nerodia*	Vertebra
7. 56	*Coluber* or *Masticophis*	Vertebra
7. 57	*Coluber* or *Masticophis*	Vertebra
7. 58	Colubridae	Vertebra
7. 59	*Lepus californicus*	Humerus-distal portion
7. 60	*Coluber* or *Masticophis*	Vertebra
7. 61	*Thamnophis* or *Nerodia*	Vertebra
7. 62	*Coluber* or *Masticophis*	Vertebra
7. 63	*Thamnophis* or *Nerodia*	Vertebra
7. 64	*Coluber* or *Masticophis*	Vertebra
7. 65	*Coluber* or *Masticophis*	Vertebra
7. 66	*Coluber* or *Masticophis*	Vertebra
7. 67	Colubridae	Condyle
7. 68	Colubridae	Condyle
7. 69	*Coluber* or *Masticophis*	Vertebra
7. 70	Colubridae	Caudal vertebra
7. 71	*Coluber* or *Masticophis*	Vertebra
7. 72	Colubridae	Condyle
7. 73	*Coluber* or *Masticophis*	Vertebra
7. 74	*Coluber* or *Masticophis*	Vertebra
7. 75	*Coluber* or *Masticophis*	Vertebra

7. 76	Colubridae	Vertebra
7. 77	Vertebrata	Unknown fragment
7. 78	Colubridae	Condyle
7. 79	Colubridae	Caudal vertebra
7. 80	*Coluber* or *Masticophis*	Vertebra
7. 81	*Thamnophis* or *Nerodia*	Vertebra
7. 82	*Coluber* or *Masticophis*	Vertebra
7. 83	Colubridae	Condyle
7. 84	*Coluber* or *Masticophis*	Vertebra
7. 85	*Thamnophis* or *Nerodia*	Vertebra
7. 86	*Coluber* or *Masticophis*	Vertebra
7. 87	*Thamnophis* or *Nerodia*	Vertebra
7. 88	*Thamnophis* or *Nerodia*	Vertebra
7. 89	*Coluber* or *Masticophis*	Vertebra
7. 90	*Coluber* or *Masticophis*	Vertebra
7. 91	*Thamnophis* or *Nerodia*	Vertebra
7. 92	Colubridae	Condyle
7. 93	Colubridae	Caudal vertebra
7. 94	*Coluber* or *Masticophis*	Vertebra
7. 95	*Coluber* or *Masticophis*	Vertebra
7. 96	*Coluber* or *Masticophis*	Vertebra
7. 97	*Coluber* or *Masticophis*	Vertebra
7. 98	*Coluber* or *Masticophis*	Vertebra
7. 99	*Coluber* or *Masticophis*	Vertebra
7. 100	Colubridae	Condyle
7. 101	Colubridae	Condyle
7. 102	*Thamnophis* or *Nerodia*	Vertebra
7. 103	Colubridae	Condyle
7. 104	Colubridae	Caudal vertebra
7. 105	*Coluber* or *Masticophis*	Vertebra
7. 106	Vertebrata	Unknown fragment
7. 107	*Thamnophis* or *Nerodia*	Vertebra
7. 108	*Coluber* or *Masticophis*	Vertebra
7. 109	*Coluber* or *Masticophis*	Vertebra
7. 110	*Coluber* or *Masticophis*	Vertebra
7. 111	Colubridae	Vertebra
7. 112	Colubridae	Caudal vertebra
7. 113	Colubridae	Caudal vertebra
7. 114	Vertebrata	Unknown fragment
7. 115	*Coluber* or *Masticophis*	Vertebra

7. 116	*Coluber* or *Masticophis*	Vertebra
7. 117	*Coluber* or *Masticophis*	Vertebra
7. 118	Vertebrata	Unknown fragment
7. 119	*Thamnophis* or *Nerodia*	Vertebra
7. 120	*Coluber* or *Masticophis*	Vertebra
7. 121	*Coluber* or *Masticophis*	Vertebra
7. 122	Colubridae	Caudal vertebra
7. 123	*Thamnophis* or *Nerodia*	Vertebra
7. 124	Vertebrata	Unknown fragment
7. 125	*Coluber* or *Masticophis*	Vertebra
7. 126	Vertebrata	Unknown fragment
7. 127	Colubridae	Caudal vertebra
7. 128	Vertebrata	Unknown fragment
7. 129	*Coluber* or *Masticophis*	Vertebra
7. 130	*Thamnophis* or *Nerodia*	Vertebra
7. 131	*Coluber* or *Masticophis*	Vertebra
7. 132	*Coluber* or *Masticophis*	Vertebra
7. 133	*Coluber* or *Masticophis*	Vertebra
7. 134	*Thamnophis* or *Nerodia*	Vertebra
7. 135	*Coluber* or *Masticophis*	Vertebra
7. 136	Vertebrata	Unknown fragment
7. 137	*Thamnophis* or *Nerodia*	Vertebra
7. 138	Vertebrata	Unknown fragment
7. 139	Vertebrata	Unknown fragment
7. 140	Vertebrata	Unknown fragment
7. 141	Vertebrata	Unknown fragment
7. 142	Vertebrata	Unknown fragment
7. 143	Vertebrata	Unknown fragment
7. 144	Vertebrata	Unknown fragment
7. 145	*Thamnophis* or *Nerodia*	Vertebra
7. 146	Colubridae	Caudal vertebra
7. 147	Colubridae	Rib
7. 148	Colubridae	Rib
7. 149	Colubridae	Rib
7. 150	Colubridae	Rib
7. 151	Colubridae	Rib
7. 152	Colubridae	Rib
7. 153	*Thamnophis* or *Nerodia*	Vertebra
7. 154	Colubridae	Rib
7. 155	*Microtus* sp.	Broken molar

7. 156	Colubridae	Condyle
7. 157	Vertebrata	Unknown fragment
7. 158	Colubridae	Tooth bearing skull bone
7. 159	Colubridae	Rib
7. 160	Colubridae	Rib
7. 161	Colubridae	Rib
7. 162	Colubridae	Rib
7. 163	Colubridae	Rib
7. 164	*Thamnophis* or *Nerodia*	Vertebra
7. 165	Colubridae	Rib
7. 166	*Coluber* or *Masticophis*	Vertebra
7. 167	Colubridae	Caudal vertebra
7. 168	Colubridae	Rib
7. 169	*Coluber* or *Masticophis*	Vertebra
7. 170	T*hamnophis* or *Nerodia*	Vertebra
7. 171	Colubridae	Rib
7. 172	Colubridae	Rib
7. 173	Colubridae	Caudal vertebra
7. 174	Colubridae	Rib
7. 175	Vertebrata	Unknown fragment
7. 176	Vertebrata	Unknown fragment
7. 177	Colubridae	Rib
7. 178	Colubridae	Rib
7. 179	Colubridae	Rib
7. 180	Colubridae	Rib
7. 181	*Coluber* or *Masticophis*	Vertebra
7. 182	Vertebrata	Unknown fragment
7. 183	Colubridae	Rib
7. 184	Colubridae	Vertebra
7. 185	Colubridae	Rib
7. 186	Colubridae	Rib
7. 187	Colubridae	Rib
7. 188	Colubridae	Rib
7. 189	Colubridae	Rib
7. 190	Colubridae	Rib
7. 191	Colubridae	Rib
7. 192	Colubridae	Rib
7. 193	Colubridae	Rib
7. 194	Colubridae	Rib
7. 195	Colubridae	Rib

7. 196	Colubridae	Tooth bearing skull bone
7. 197	Colubridae	Rib
7. 198	Colubridae	Rib
7. 199	Colubridae	Rib
7. 200	Colubridae	Tooth bearing skull bone
7. 201	Colubridae	Rib
7. 202	Colubridae	Tooth bearing skull bone
7. 203	Colubridae	Rib
7. 204	Colubridae	Rib
7. 205	Vertebrata	Unknown fragment
7. 206	Colubridae	Rib
7. 207	Colubridae	Rib
7. 208	Colubridae	Rib
7. 209	Colubridae	Rib
7. 210	Colubridae	Condyle
7. 211	Colubridae	Caudal vertebra
7. 212	Colubridae	Caudal vertebra
7. 213	*Reithrodontomys* sp	1st upper molar
7. 214	Colubridae	Caudal vertebra
7. 215	Centrum	Osteichthyes
7. 216	Colubridae	Caudal vertebra
7. 217	*Coluber* or *Masticophis*	Vertebra
7. 218	Colubridae	Caudal vertebra
7. 219	Colubridae	Caudal vertebra
7. 220	Mammalia	Incisor
7. 221	Colubridae	Rib
7. 222	*Coluber* or *Masticophis*	Vertebra
7. 223	*Coluber* or *Masticophis*	Vertebra
7. 224	Vertebrata	Unknown fragment
7, 225	Mammalia	Caudal vertebra
7. 226	*Thamnophis* or *Nerodia*	Vertebra
7. 227	*Reithrodontomys* sp.	3rd lower molar
7. 228	Mammalia	Metapodial
7. 229	Colubridae	Tooth
7. 230	Colubridae	Rib
7. 231	*Coluber* or *Masticophis*	Vertebra
7. 232	Vertebrata	Unknown fragment
7. 233	Colubridae	Caudal vertebra
7. 234	Colubridae	Caudal vertebra
8. 1	*Reithrodontomys* sp.	Broken molar

8. 2	*Thamnophis* or *Nerodia*	Centrum
8. 3	Mammalia	Metapodial
8. 4	Colubridae	Tooth
8. 5	Colubridae	Tooth
8. 6	*Thamnophis* or *Nerodia*	Centrum
8. 7	Colubridae	Caudal vertebra
8. 8	Colubridae	Caudal vertebra
8. 9	Colubridae	Caudal vertebra
8. 10	*Coluber* or *Masticophis*	Vertebra
8. 11	*Synaptomys cooperi*	1st upper molar
8. 12	*Lepus californicus*	Lower premolar or molar
8. 13	*Microtus* sp.	1st upper molar
8. 14	*Microtus* sp.	2nd upper molar
8. 15	Mammalia	Incisor
8. 16	*Coluber* or *Masticophis*	Vertebra
8. 17	*Coluber* or *Masticophis*	Vertebra
8. 18	*Synaptomys cooperi*	2nd upper molar
8. 19	*Coluber* or *Masticophis*	Vertebra
8. 20	*Geomys* sp.	Premolar
8. 21	*Lepus californicus*	Incisor
8. 22	*Coluber* or *Masticophis*	Vertebra
8. 23	Mammalia	Incisor
8. 24	*Lepus californicus*	Upper premolar or molar
8. 25	Colubridae	Caudal vertebra
8. 26	*Coluber* or *Masticophis*	Vertebra
8. 27	*Coluber* or *Masticophis*	Vertebra
8. 28	*Coluber* or *Masticophis*	Vertebra
8. 29	*Coluber* or *Masticophis*	Vertebra
8. 30	*Lepus californicus*	Metapodial
8. 31	*Elaphe bairdi*	Vertebra
8. 32	Colubridae	Tooth bearing skull bone
8. 33	*Reithrodontomys* sp.	Lower 1st molar
8. 34	Vertebrata	Unknown fragment
8. 35	Colubridae	Tooth
8. 36	*Reithrodontomys* sp.	Upper 1st molar
8. 37	*Reithrodontomys* sp.	Lower 1st molar
8. 38	Colubridae	Tooth
8. 39	Colubridae	Tooth bearing skull bone
8. 40	*Reithrodontomys* sp	Lower 1st molar
8. 41	*Coluber* or *Masticophis*	Vertebra

8. 42	Vertebrata	Unknown fragment
8. 43	*Synaptomys cooperi*	Upper 3rd molar
8. 44	Coluber or Masticophis	Vertebra
8. 45	*Lepus californicus*	Lower premolar or molar
8. 46	*Lepus californicus*	Upper premolar or molar
8. 47	*Lepus californicus*	Upper premolar or molar
8. 48	*Lepus californicus*	Lower premolar or molar
8. 49	*Lepus californicus*	Upper premolar or molar
8. 50	*Lepus californicus*	Upper premolar
8. 51	Mammalia	Incisor
8. 52	*Sorex* or *Notiosorex*	Lower molar
8. 53	*Reithrodontomys* sp.	Upper 1st molar
8. 54	Vertebrata	Unknown fragment
8. 55	Colubridae	Tooth
8. 56	*Thamnophis* or *Nerodia*	Vertebra
8. 57	Colubridae	Tooth bearing skull bone
8. 58	Mammalia	Incisor
8. 59	*Thamnophis* or *Nerodia*	Vertebra
8. 60	*Thamnophis* or *Nerodia*	Vertebra
8. 61	*Microtus* sp.	Broken molar
8. 62	*Elaphe bairdi*	Vertebra
8. 63	Colubridae	Tooth bearing skull bone
8. 64	Colubridae	Tooth
8. 65	Mammalia	Phalanx
8. 66	*Coluber* or *Masticophis*	Vertebra
8. 67	*Reithrodontomys* sp.	Upper 3rd molar
8. 68	Colubridae	Caudal vertebra
8. 69	*Microtus* sp.	Broken molar
8. 70	Mammalia	Incisor
8. 71	*Thamnophis* or *Nerodia*	Vertebra
8. 72	Vertebrata	Unknown fragment
8. 73	Colubridae	Tooth
8. 74	*Reithrodontomys* sp.	Lower 2nd molar
8. 75	Colubridae	Tooth bearing skull bone
8. 76	Colubridae	Caudal vertebra
8. 77	Vertebrata	Unknown fragment
8. 78	*Synaptomys cooperi*	Broken molar
8. 79	Vertebrata	Unknown fragment
8. 80	*Thamnophis* or *Nerodia*	Vertebra
8. 81	Mammalia	Metapodial

8. 82	Mammalia	Incisor
8. 83	Colubridae	Tooth
8. 84	Vertebrata	Unknown fragment
8. 85	*Lepus californicus*	Centrum
8. 86	*Lepus californicus*	Humerus-distal portion
8. 87	*Lepus californicus*	Humeral shaft
8. 88	*Lepus californicus*	Humeral shaft
8. 89	*Lepus californicus*	Centrum
8. 90	*Coluber* or *Masticophis*	Vertebra
8. 91	*Thamnophis* or *Nerodia*	Vertebra
8. 92	*Elaphe bairdi*	Vertebra
8. 93	*Coluber* or *Masticophis*	Vertebra
8. 94	Colubridae	Rib
8. 95	*Coluber* or *Masticophis*	Vertebra
8. 96	*Coluber* or *Masticophis*	Vertebra
8. 97	*Thamnophis* or *Nerodia*	Vertebra
8. 98	*Thamnophis* or *Nerodia*	Vertebra
8. 99	*Coluber* or *Masticophis*	Vertebra
8. 100	*Coluber* or *Masticophis*	Vertebra
8. 101	*Lepus californicus*	Palatine
8. 102	*Lepus californicus*	Humerus-distal portion
8. 103	*Lepus californicus*	Femur-proximal portion
8. 104	*Lepus californicus*	Tibia-proximal portion

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