Late Pleistocene Remains of an American Black Bear (*Ursus americanus*) and Two Small Vertebrates from an Oklahoma Ozark Cave

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Abstract: The serendipitous discovery of fossil bear bones in a cave in northeastern Oklahoma prompted us to excavate and describe the fossils and their geologic, chronologic, and biogeographic context. We recovered the partial skeleton of a subadult (about 1-2 year-old) male *Ursus americanus* (American black bear) in CZ-9 Cave, Cherokee County, Oklahoma, in late Pleistocene fill sediments within the cave. The locality is at the western edge of the Ozark Highlands. A sample of enamel from a tooth of the bear yielded an AMS radiocarbon age of 10,958 ± 35 years before present. This is the first directly-dated occurrence of a black bear in the late Pleistocene of the western Ozark Highland and in Oklahoma. Two vertebrae of an unidentified snake were found in the same layer as the bear's remains and may be approximately contemporaneous. Fragmentary jaws and teeth of a large species of *Blarina* (short-tailed shrew) occurred in the same sedimentary unit as those containing the bear and also in another unit above them. This large shrew differs from the related smaller species *Blarina hylophaga* (Elliot's Short-tailed Shrew) that currently occupies the same region of eastern Oklahoma, but the fossils cannot be identified to species. The shrew fossils, too, are probably of late Pleistocene age; they may pertain to an ancestral population of larger body size than the extant local species and are about the size of extant *Blarina brevicauda* (Northern Short-tailed Shrew). They indicate a biogeographic or evolutionary change since the late Pleistocene in the short-tailed shrew inhabiting the Oklahoma portion of the Ozark Highland.

Introduction

The American black bear, *Ursus americanus* Pallas, is known in the historic and recent fauna of Oklahoma, including the western part of the Ozark Highland. However, these bears are poorly known as confirmed Pleistocene fossils in this area although they are common as Holocene fossils in other parts of the Ozarks (Hawksley 1986, Graham and Lundelius 2010). We report herein a late Pleistocene occurrence of a black bear and two associated microvertebrates from a cave in the western Ozark Highland in Oklahoma.

Ursine bears (family Ursidae, subfamily Ursinae) are known as fossils or subfossils from several localities in Oklahoma. Previous Quaternary fossil records include three that were originally reported as brown bears or grizzly bears (*Ursus arctos* Linnaeus or *U. horribilis* Ord). Smith and Cifelli (2000) reviewed the Oklahoma records. Stovall and Johnston (1935) reported two bear skulls, one of which originated near Lawton, Comanche County (Oklahoma Museum of Natural History [OMNH] 9569). The other was found near Cheyenne, Roger Mills County in western Oklahoma. The second specimen was recently in the Black Kettle Museum, Cheyenne, Oklahoma (J. P. Thurmond, in litt.) and was cataloged as Museum of the University of Oklahoma [MUO] 546. Unfortunately, the Black Kettle Museum no longer exists and the disposition of this loaned specimen is unknown; the skull was not returned to the OMNH and its present whereabouts are unknown. Both skulls were found in Quaternary alluvium. As was common practice at the time, Stovall and Johnston (1935) named a new subspecies "tentatively identified as *U[rsus] horribilis oklahomensis*" based on these specimens. However, Graham (1991) showed that these specimens actually represented black bears, *U. americanus*, not brown bears, *Ursus arctos.* Czaplewski et al. (1994) further noted that *Ursus horribilis oklahomensis* was a *nomen nudum*; no type specimen was designated and no diagnosis was given, and few measurements were provided. Thus, the name *Ursus horribilis oklahomensis* has no validity. Stovall (1936) reported a skull and associated right and left femora (OMNH 10735) as *U. horribilis nelsoni* from Quaternary lacustrine deposits near Lenora, Dewey County (OMNH locality V689) in west-central Oklahoma; the specimen actually represents *U. americanus* (pers. observ.). Stangl and Dalquest (1986) and Stangl et al. (2014) reported a subfossil (undated but probably Holocene in age) lower jaw of *U. americanus* from the Red River, Tillman County. Martin and Meehan (2003) listed a metatarsal III from the Burnham site (late Pleistocene) in Woods County as *Ursus* cf. *U. americanus*. Several unpublished black bear specimens from Oklahoma are housed in the OMNH VP collection, including a cranium from near Buffalo, Harper County, a crushed cranium from Rosedale, McClain County, and pieces from sand and gravel bars along the Arkansas and Canadian Rivers. In addition, William Caire (pers. comm.) indicated that the University of Central Oklahoma has a specimen from the Selman Cave System, Woodward County, and there is a partial skeleton in the museum at Northwest Oklahoma State University collected from a sand dune deposit of probable Holocene age near Mooreland, Woodward County. None of these specimens has been radiometrically dated, so all can be considered Holocene or possibly late Pleistocene in age. In the late Holocene at least two Oklahoma archaeological localities are reported to contain Black Bear remains, the Pohly site (34My54), Mayes County, and Bryson-Paddock (34Ka5), Kay County. The Pohly site is dated by relative dating only, with cultural materials indicating an age range for the site of 2,950 to 55 years before present (ybp; Ray 1965). The Bryson-Paddock site has several radiometric dates ranging from 290 ± 70 radiocarbon ybp (rybp) to modern (Bell 1984). To these Quaternary records we add another fossil black bear, represented by a partial skeleton and the first occurrence to be dated directly to the late Pleistocene.

In the late Pleistocene during the full-glacial (approximately 18,000 rybp), the southwestern portion of the Ozark Highland including what is now in eastern Oklahoma was covered with boreal forest based on pollen cores analyzed by Delcourt and Delcourt (1987, 1991); this forest was dominated by spruce and jack pine and included few deciduous trees. During the late glacial about 12,000 rybp, prairie was established in the eastern Great Plains including eastern Oklahoma, and oak-hickory forest with deciduous broadleaf trees (oak, ash, elm, hickory, hornbeam) moved into the southeastern Ozark Highland as conifers declined there by about 14,000 to 10,000 rybp (Albert and Wyckoff 1981, Bryant and Holloway 1985, Delcourt and Delcourt 1991). Whether black bears remained continuously in the Ozark Highland during the Pleistocene glaciations is not yet addressed by genomic studies of these mammals. There are late Pleistocene fossil records of black bears in the Ozarks, but these are spotty and not well dated radiometrically (Graham and Lundelius 2010). Blaine Schubert (pers. commun.) feels there are likely more Pleistocene occurrences in the Ozarks than published records would suggest, but these are as yet unpublished and undated. There are no previous records of black bears from the Ozarks in Oklahoma, but there are two in Arkansas (Hurricane River Cave and

Peccary Cave) and several in Missouri. Changes in the climate and burning of the habitat after human arrival probably resulted in a mix of open prairies and woodlands in the Holocene that could have affected the distribution of black bears. Many plants of the Pleistocene boreal forest retreated northward at the same time as indigenous peoples and lightning-caused fires kept parts of the habitat open (Buckner 1989, Foti and Glenn 1991, Masters et al. 1995).

In the 1500s when Hernando de Soto entered the Ozark region, he recorded a land dominated by prairies with trees restricted to the drainages (Beilmann and Brenner 1951). After the invasion of the region by Europeans and the decline of the native peoples, suppression of fires resulted in the present-day closed-canopy oak-hickory forest in the Oklahoma Ozarks (Tyrl et al. 2002). The resulting near-disappearance of herbivorous prey animals such as elk, bison, and pronghorns from Oklahoma, as well as subsequent fragmentation and conversion of the forest habitat for agricultural, grazing, logging, and urban development, contributed to the disappearance of predators such as bears and wolves, which were also removed by humans because they were considered a threat. Black bears were occasional in Oklahoma in the early 1800s, including among other instances a sighting along the Grand River (Neosho River) in 1823 (Tyler and Anderson 1990) near CZ-9 Cave. Black bears were extirpated from Oklahoma by 1915 and nearly extirpated from adjacent Arkansas by the 1940s (Clark and Smith 1994). However, they reentered eastern Oklahoma forests during the mid-1980s, and genetic studies show they came from remnant Arkansas or Missouri black bear populations and individuals that were reintroduced in the Arkansas Ozark and Ouachita mountains in the 1950s-1960s from populations in Manitoba and Minnesota (Csiki et al. 2003, Faries et al. 2013, Smith and Clark 1994, Van Den Bussche et al. 2009). In Oklahoma, black bear distribution and abundance have increased over the last two decades in the Ozarks and Ouachita Mountains (Jackson et al. 2014).

Methods

In the process of conducting biodiversity surveys in Ozark caves in northeastern Oklahoma during July 2005, WLP noticed bear bones in CZ-9 Cave. The bones appeared in a small collapse of sand and silt from a bank of stratified sediments in a small, low passage. The cave is located along a small tributary of the Neosho River near its confluence with the Verdigris and Arkansas rivers in Cherokee County, Oklahoma. In this part of Oklahoma, the Neosho River and Arkansas River form the western boundary of the Ozark Highland. Thus CZ-9 Cave is at the very western boundary of the Ozark Highland physiographic region (Fig. 1). In historic times, vegetation of the region near the cave was predominantly oak-hickory forest on the uplands, with some post oak-blackjack oak (cross timbers) forest, and bottomland forest along the river floodplains. The authors visited the cave in February and July 2006 to excavate and collect the bones.

CZ-9 Cave (Fig. 1) formed within the Pitkin Formation, which is of Mississippian age. The Pitkin Formation is composed primarily of limestone with thin black shale interbeds. The formation is about 12 m thick in an area 3 km northwest of CZ-9 cave, based on a measured section in Huffman (1958). The cave has a mapped length of 600+ m and shows two levels of horizontal development. Small vertical shafts connect the horizontal passages to one another.

The cave entrance opens at about 180 m elevation. The bear bones were recovered in the lower level horizontal passage 88 m from the entrance. The fossil site within the cave is recorded as Oklahoma Museum of Natural History (OMNH) locality V1510. The bones were in a passage with a low ceiling varying from about 0.5 to 1 m high and 1 to 10 m wide (Figs. 1, 2). This passage drains northward toward the entrance and was barely damp to dusty when we visited it during the very dry winter and summer of 2006. Large deposits of damp, weakly consolidated or unconsolidated sediments formed banks on either side of the stream crawlway. Given the radiometric date on the bear, these sediments probably represent late Pleistocene aggradation within the cave. The sediment banks reached a thickness ranging from halfway to the ceiling

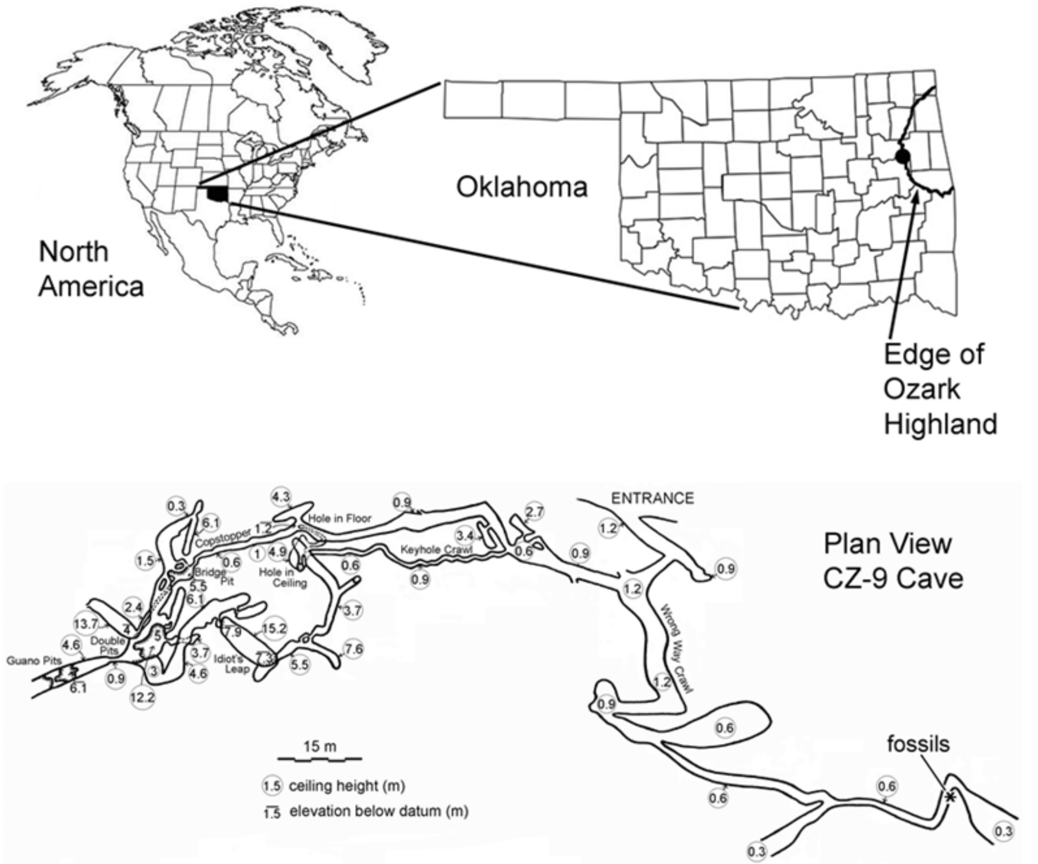

Figure 1. Locator maps (top) and plan view (bottom) of CZ-9 Cave, Cherokee County, Oklahoma, with location of Black Bear and other fossils indicated. North is at top. Black dot indicates location of CZ-9 Cave at western edge of Ozark Highland. Ceiling heights and elevations are in meters (m). Map produced by, and courtesy of, the Tulsa Regional Oklahoma Grotto (TROG).

to within a few cm of the ceiling in some places, such that this portion of the cave was nearly filled with Pleistocene deposits except where the stream channel cut through to form the crawlway. Sediments are currently being removed from the lower level of the cave by episodic underground drainage; in part, this erosion contributed to exposing the cross-sectional profile of sediments and the fossils described in this report.

Along this part of the cave passage most of the sediments that formed the walls of the crawlway showed a weathered surface that was blackish and pitted on its top surface near the ceiling, and was encrusted with whitish and pale yellow carbonate and probably other minerals on its vertical walls facing the crawlway. A small portion of the west bank of the sedimentary fill had collapsed along the stream-channel crawlway, exposing well-stratified sandy to clayey beds in a clean profile. Several black bear bones occurred in the collapsed sediment including a femur shaft lacking proximal and distal epiphyses, a carbonate-encrusted partial hand or foot with one ungual phalanx, and two other fragments of long bones. Cross-sections of other bones were visible in the layered sediment in the wall of the passage (Fig. 3).

We used small folding shovels and trowels to clean the stratigraphic profile and render the strata more visible, as well as to remove the

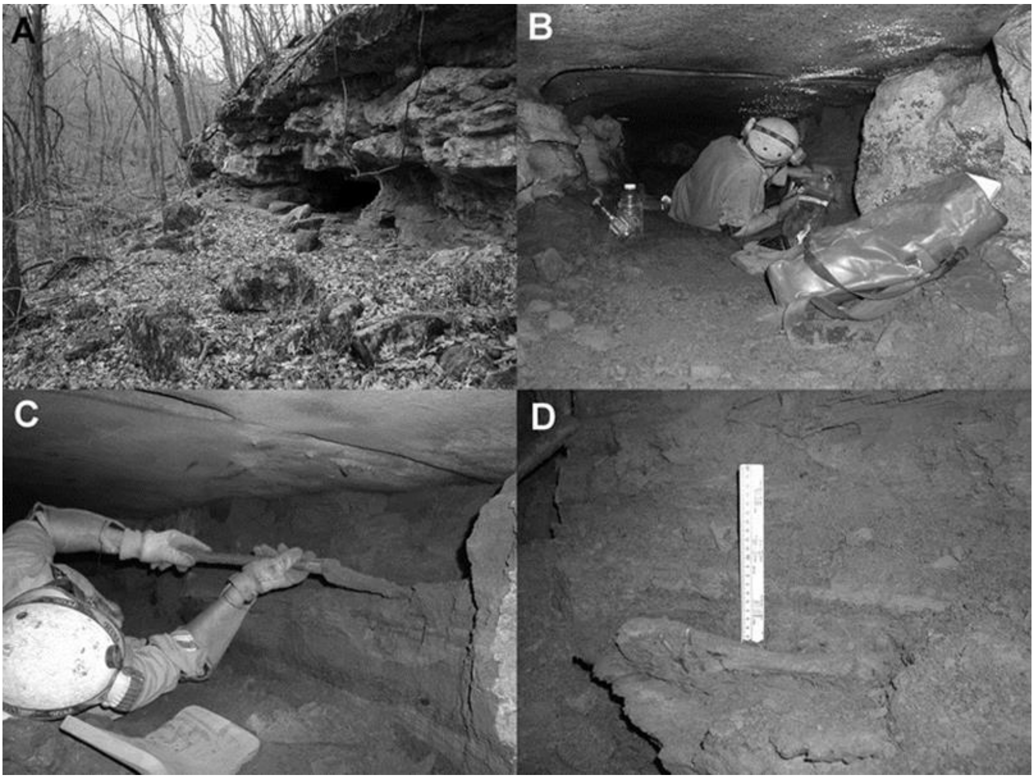

Figure 2. Photographs of CZ-9 Cave, Cherokee County, Oklahoma. A, cave entrance in Pitkin Limestone, winter aspect (February 2006); view is approximately west. B, view into the cave of the passage at the bear bone-containing deposit. C, removing overburden in the deposit; note the faint channel cut-and-fill directly below the shovel head. D, detail at the left (south) side of the deposit showing partly exposed (mud-covered) long bone and two adjacent canines in nearly upright positions; ruler is 200 mm long.

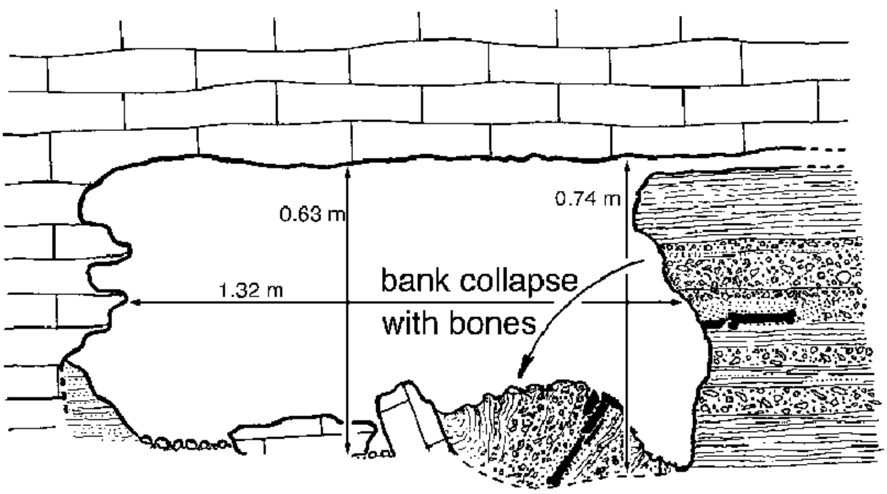

Figure 3. Cross-section of passage at the site of the bear bones as originally discovered. Curved arrow indicates fall of deposits; solid black indicates bear bones exposed by the collapse. Passage heights and width are indicated. View is into the cave.

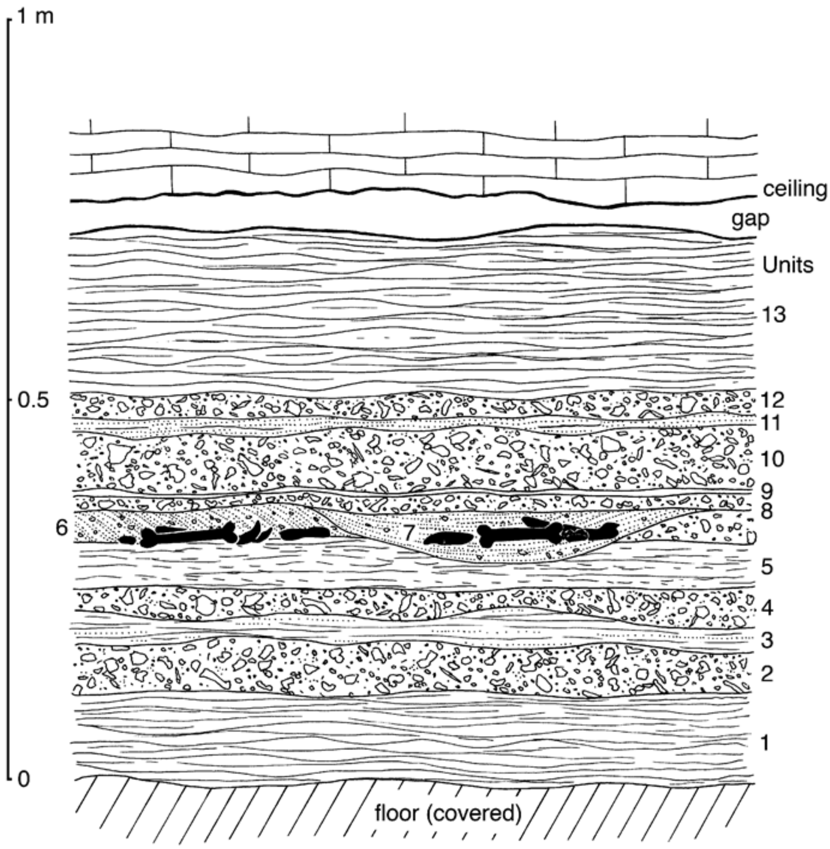

Figure 4. Profile of deposit containing black bear bones in CZ-9 cave. Entrance of cave is toward the right and approximately north. View is to the west. Stratigraphic units are indicated by numbers corresponding to those in the measured profile in text. Solid black indicates bear fossils.

fossils from the intact sediments in the wall of the passage and in the bone-containing sediment that had collapsed from the wall onto the floor of the cave passage. We photographed, sketched, and measured the cleaned profile, in which the bones occurred about halfway up the deposit in a small channel cut-and-fill and adjacent sandy foreset beds. Above and below the sandy beds containing bear bones were deposits of gravels, sands, silts, and clays indicating periodic flooding events. These are documented in the description (below) and sketch of the profile (Figs. 4, 5). Several long bones and a few loose teeth from the bear were found in the channel fill (Unit 7) and foresets (Unit 6) including two incisors, an m3, three of the canines, an articulated manus and partial pes, a femur, and fragments (Fig. 6). Sediment samples dug from the deposit adjacent to the bear bones were bagged and later screenwashed using nested wooden boxes with metal screen bottoms consisting of a coarse mesh of window screen (ca. 1.2 mm openings) on the inner box and a fine mesh (0.6 mm) on the outer box. Fine sediments of clay, silt, and fine sand were washed away in water tanks. The resulting concentrate of coarse sand, pebbles, and fossils in the bottom of the screens was dried and picked under a dissecting microscope to sort out and save the small fossils contained within it. The fossils were cleaned, cataloged, and are curated in the Vertebrate Paleontology collection of the

OMNH. Fossils were identified by comparison with recent specimens preserved in the collections of the OMNH and by consulting relevant literature sources. The taxonomic identifications are provided in the Systematic Paleontology section of Results.

In order to estimate the geological age of the cave deposit, we submitted enamel and dentine fragments of the broken left upper canine from the black bear specimen. The sample was sent to Rafter Radiocarbon Laboratory, New Zealand, for accelerator mass spectrometry (AMS) radiocarbon dating. The tooth was photographed before and after sampling for dating. Processing of the tooth enamel and dentine by Rafter included washing with sodium hypochlorite and acetic acid, etching in HCl, grinding with pestle and mortar, and finally treating through a phosphoric acid sequence. Because of the condition of the dentin, only the enamel fraction of the sample was ground and dated; the carbon/nitrogen ratio was not determined.

Results

Geologic age of the bear and cave deposit

The radiocarbon age yielded by AMS dating of the bear tooth is 10,958 ± 35 rybp (sample result archived as NZA 37942). This places the black bear fossils in the latest part of the Pleistocene epoch, specifically during the time of the deglaciation following the last glacial maximum, which is sometimes called the Wisconsinan glacial. This radiometric date gives an approximate age to the stratigraphic unit (Unit 6) in which the bear skeleton was found. Stratigraphic units lower in the profile are assumed to be relatively older and units above that containing the bear are likely somewhat younger. No datable materials were recovered in the other stratigraphic units. In the absence of datable materials from the other units, we assume the adjacent units are also of latest Pleistocene age.

Description of stratigraphic profile

Units were numbered from bottom to top (Fig. 4). Colors were recorded when the matrix was still damp. Colors given Munsell Soil Color codes were recorded under sunlight; those without Munsell codes were recorded under caving lights in the cave.

Unit 1. Silt; medium brown; thickness 130 mm.

Unit 2. Gravel consisting of clay-pebble and other gravel-sized clasts in a silty and sandy matrix; dark brown and gray; thickness 55-65 mm. Many of the clasts are very dark gray (charcoal gray, clearly derived from the Pitkin Formation black shales), and freshly broken ones at the face of the profile or crushed with the fingers appear black but smear grayish.

Unit 3. Clays, silts and sands; mostly pale buff but mixed with some grayish, yellowish, and tan, with rust-colored (limonite?) streaks; thickness 20-45 mm.

Unit 4. Gravel, dark gray to grayish brown; similar in composition and color to Unit 2; thickness 15-45 mm.

Unit 5. Silt; medium brown, grayish, and rust-tan; thickness 60 mm.

Unit 6. Sand with some gravel; mixed red, black, brown, buff, and gray. Foreset-like cross-bedding advancing to the right (toward the cave entrance); thickness 40 mm. Contained two snake vertebrae and several of the bones of the black bear (see Fig. 6). Bones were lightly to moderately encrusted with rusty dark brown carbonate and sand, but the teeth were not so encrusted. Two canine teeth were sitting tips-upward against the end of a long bone.

Unit 7. Sand with some silt and a little gravel, filling a small channel cut into Units 5 and 6; pale buff (Munsell color: 5YR 4/2 to 7.5 YR 4/2 or 5/2) with limonite streaks and stains; thickness at deepest point 75 mm. Bear fossils occurred within the channel fill at a level above the middle of its deepest point and at the same level as the bones in Unit 6. The fossils in this unit included a canine tooth, an unworn m3, and a large unidentified fragment. Bones were heavily encrusted with carbonate; teeth were not encrusted.

Unit 8. Gravel with some sand; similar to Units 2 and 4; thickness 5-25 mm.

Unit 9. Clay; pale buff and gray brown; thickness 5 mm.

Unit 10. Gravel; similar to Units 2, 4, and 8; Munsell color: 5YR 4/4 to 10 YR ¾; thickness

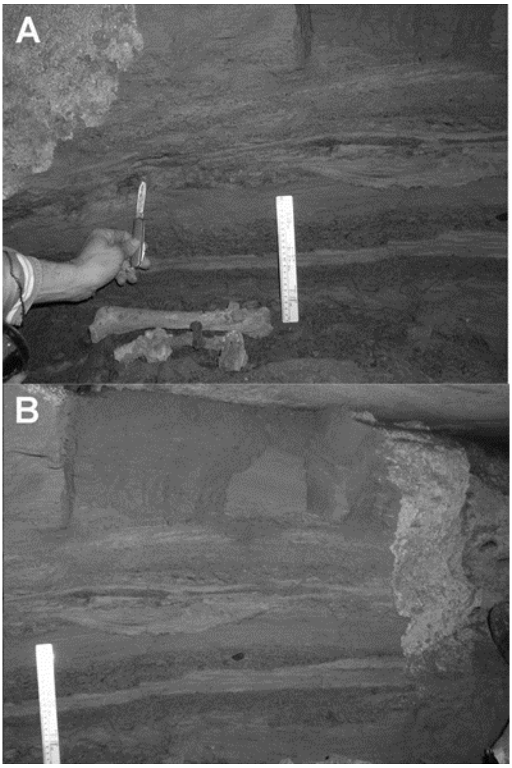

Figure 5. Photographs of same profile as diagrammed in Fig. 4, after collapse and before beginning of excavation. A, left (south) end of deposit before excavation. Pocketknife tip points to the exposed cross-section of a long bone broken in the collapse and buried in the foreset beds of Unit 6. Note also the sandy channel cut-and-fill (Unit 7, at right center) that contained some of the bear bones, and loose bones on floor (at lower left) that were pulled from the collapsed material. Cave entrance is toward the right (and north); Ruler at bottom center is 200 mm long. B, right (north) end of deposit before excavation. The sandy channel cut-and-fill shows at left center. Note carbonate-encrusted pre-collapse face of the deposit at right, and limestone ceiling of passage across the top of the photo. About 195 mm of the ruler is showing.

80 mm. Screenwashing of a sample of this unit yielded a shrew jaw fragment.

Unit 11. Clay and sand; pale buff; thickness 5 mm.

Unit 12. Gravel; dark brown and gray (Munsell color: 5YR 4/4 to 10 YR ¾); similar to Units 2, 4, 8, and 10; thickness 30 mm.

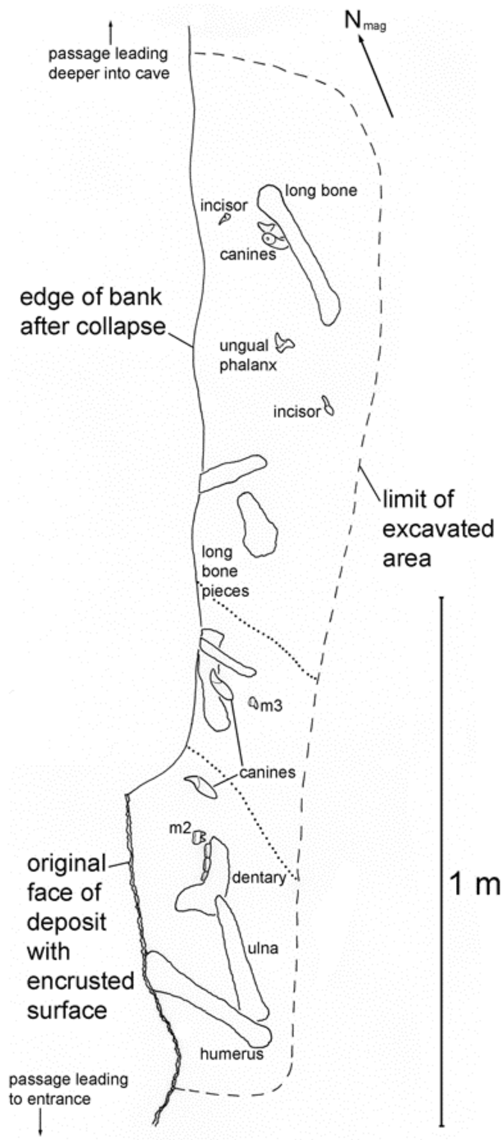

Figure 6. Plan view of excavated portion (dashed line) of the late Pleistocene sedimentary deposit showing relative positions of black bear bones in place. Dotted lines indicate approximate boundaries of sandy channel fill. Most bones were heavily encrusted with gravel and not identifiable in situ, but enamel tooth crowns were not so encrusted.

Unit 13. Silt; medium brown at top and bottom, orange or rust-colored zone above the middle (Munsell color: about 5YR 4/3);

thickness 210 mm. Top of deposit with blackish crust on top of the pitted surface.

Total thickness about 705 mm.

There is a gap of 3-5 cm between the top of the deposit and the limestone ceiling at this and most of the deposits along this passage of the cave. Some of the weathered cross-sectional faces of the Quaternary fill banks have thin white and yellow carbonate deposits forming a surface rind on them. Other areas have thick carbonate crusts, especially over the clay layers.

In the process of excavating the bear bones, we removed overburden from the fill bank in levels corresponding to the units in our measured profile, saving samples to be screenwashed. We sampled matrix for screening from Units 13, 10, 9, 8, 7, and 6. A few more teeth and small bones of the bear were recovered by screenwashing from the same sandy layers (Units 6 and 7) in which the larger bear bones occurred, as well as two types of small vertebrates. Specimens are preserved in the Vertebrate Paleontology collection of the OMNH.

Systematic paleontology

In addition to the vertebrates described below, a single plant fossil, one-half of a carbonate-containing endocarp of *Celtis* sp. (hackberry) was recovered from a screenwashed sample of Units 6 and 7. The age of the specimen is unknown.

Class Reptilia

Order Squamata (Lizards and Snakes)

Family undetermined

Material. Two partial trunk vertebrae (OMNH 73939) from a snake or possibly two different snakes were found by screenwashing the sediments from Unit 6. The specimens are incomplete, waterworn, and preserve insufficient morphological characters for generic identification (Fig. 7).

Discussion. Descriptive terminology for snake vertebrae follows LaDuke (1991) and Holman (2000); classification follows Collins (2006) and the Center for North American Herpetology (2012). In the somewhat more complete, smaller of the two vertebrae (Fig. 7A-D) the neural arch is depressed, the neural spine is thin where preserved at its base, the zygosphene appears to have a concave anterior dorsal profile, the prezygapophyseal and postzygapophyseal articular facets are oval to ovoid, the hemal keel is gladiate to spatulate in ventral view, and the subcentral grooves are shallow and weak. In the much less complete, larger vertebra (Fig. 7E-H) the neural arch is moderately vaulted; the hemal keel is robust and spatulate in ventral view. Subcentral grooves are absent. The phylogenetic appropriateness of these morphological features has not been assessed across the various taxa of snakes. Other morphological characters in both vertebrae are broken or obscured.

The CZ-9 Cave snake vertebrae clearly do not pertain to the families Boidae (Boas), Crotalidae (pitvipers), or Leptotyphlopidae (slender blind snakes). They also lack the hypapophysis of Natricidae (water snakes) and Elapidae (coral snakes) vertebrae. The bones probably represent a member of either the Colubridae (harmless egg-laying snakes) or Dipsadidae (rear-fanged snakes); both families encompass a large diversity of genera and species. The fossils contain no reliable criteria on which to base a familial or generic identification.

Class Mammalia

Order Soricomorpha

Family Soricidae

Blarina Gray (short-tailed shrews)

Blarina species indeterminate

Material. OMNH 73938, right i1 and associated m1-m2 in a small fragment of dentary (Fig. 8A-D); and 73937, partial left dentary with m3 (Fig. 8E-H).

Discussion. The only mammal other than the black bear recovered by screenwashing the stratigraphic units at CZ-9 was a short-tailed shrew, *Blarina* sp. The right lower incisor and the right m1-m2 came from screenwashed concentrate of Units 5 and 6, below and in the

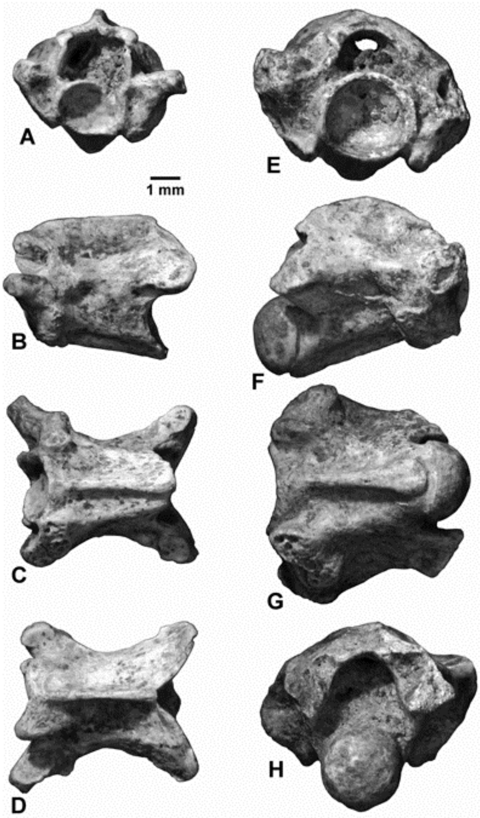

Figure 7. Snake vertebrae (OMNH 73939) from CZ-9 Cave, Cherokee County, Oklahoma. A-D, smaller partial mid-trunk vertebra in (A) anterior, (B) left lateral, (C) ventral, and (D) dorsal views. E-H, larger partial mid-trunk vertebra in (E) anterior, (F) right lateral, (G) ventral, and (H) posterior views.

same unit as some of the bear bones. The dentary was found in screenwashed concentrate from Unit 10, a thick gravel unit above the bear bones. The separate instances and preservation indicate that the material represents at least two individual shrews.

Measurements (in mm) of the shrew specimens as defined by Carraway (1995) are: height of coronoid process, 6.2; length of coronoid-condyloid processes, 5.7; length of i1, 6.2; length of m1, 2.27; width of m1, 1.62; height of pigmented portion of m1, 1.10; height of unpigmented portion of m1, 0.85; length of m2, 1.90; width of m2, 1.35; length of m3, 1.60; width of m3, 0.87. Quantitatively, the CZ-9 shrew specimens are larger than *Blarina carolinensis* (southern short-tailed shrew) and similar in size to *Blarina brevicauda* (northern short-tailed Shrew). However, *Blarina hylophaga* (Elliott's short-tailed shrew) and *B. brevicauda* overlap in size and thus the two cannot be differentiated on this basis.

The falciform lower incisor has two denticulations (terminology of Carraway, 1995). The partial dentary bone includes the ascending ramus and the horizontal ramus forward to the level of the posterior alveolus of m1 (with empty alveoli for m1 and m2) and laterally the posteriormost edge of the i1 alveolus; the angular process is broken off (Fig. 8E, H). The mental foramen is situated below the posterior alveolus of m1. In those features that are preserved in the available specimens, by comparison with the extinct early Pleistocene (Irvingtonian land mammal age) species *Blarina ozarkensis* (as diagnosed by Graham and Semken, 1976; sometimes considered a subspecies of *B. brevicauda*), the CZ-9 Cave shrew has less inflated cingula on the lower molars and a less reduced talonid on m3.

George (2012) critically re-examined morphological characters used by previous authors to distinguish late Pleistocene and recent shrews and searched for apomorphic morphological characters that could be used to differentiate complete or fragmentary fossils of North American shrews, including three of the four *Blarina* extant species recognized on the basis of molecular genetics (the fourth being *Blarina shermani* [Sherman's short-tailed shrew] recently described and based on a geographically restricted population in Florida [Benedict et al. 2006]). George (2012) found several synapomorphies supporting the genus *Blarina* as distinct from other shrew genera and showing that the genus was monophyletic. However, he had difficulty using these characters to distinguish among the three recent species of *Blarina* that he studied. Because of polymorphisms within the genus, late Quaternary fossils of *Blarina* are virtually impossible to assign to a species (George 2012).

We scored the qualitative morphological character states: (1) that are available or unobscured by concreted matrix in the CZ-9

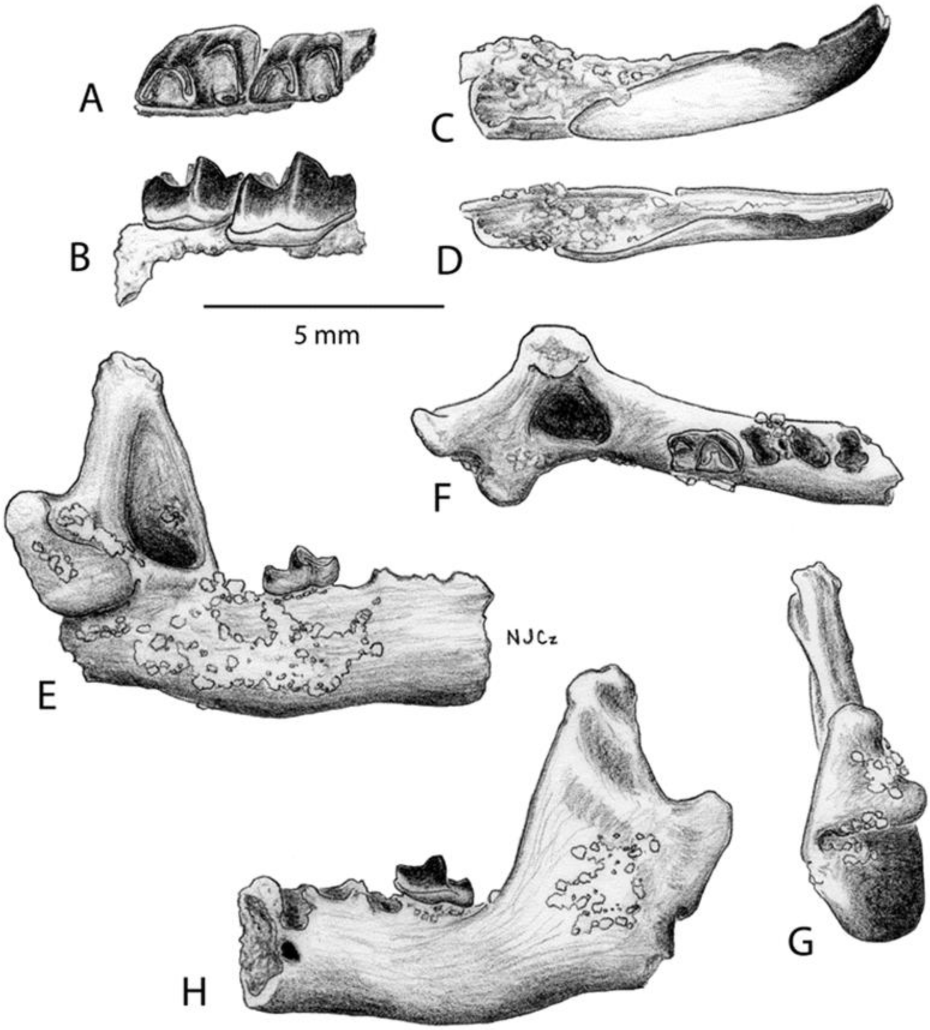

Figure 8. Short-tailed shrew (*Blarina* sp.) fossils recovered from CZ-9 Cave, Cherokee County, Oklahoma. A-B, OMNH 73938, right m1-m2 in small fragment of dentary in A, occlusal view, and B, labial view. C-D, OMNH 73938, right i1 in C, labial view, and D, occlusal view. E-H, OMNH 73937, left dentary with m3 in E, lingual view, F, occlusal view, G, posterior view showing mandibular condyles, and H, labial view.

Cave specimens, and (2) which do not exhibit identical states for all three species of *Blarina* as determined by George (2012). Character states for the CZ-9 specimens (listed here following George's [2012] character and state numbers in parentheses) are: (1:1) teeth pigmentation: heavy; (3:1) interdenticular spaces on i1: shallow; (5:3) posterior extent of i1 in labial view: past metaconid of m1 (as judged on the posterior alveolus rim and m1 alveoli preserved in the dentary OMNH 73937); (7:0) upturning of distal tip of i1: strong; (9:1) talonids of m1 and m2: equivalent in size to trigonids; (12:1) cusps on talonid of m3: two, both hypoconid and entoconid; (13:1) coronoid spicule: strong; (14:1) tip of coronoid process relative to base: wide; and (22:1) size of internal temporal fossa of dentary: medium. These character states occur in all three species *B. brevicauda*, *B. hylophaga*, and *B. carolinensis*, precluding species assignment of the CZ-9 Cave fossils.

Figure 9. Black bear teeth and jaw bones recovered from Cz-9 Cave in labial view. Top row, from left to right: right P3, right C1, right I3, left I3, left C1 (lingual side of this tooth was sampled for AMS radiocarbon date, NZA 37942). Middle row: coronoid process of right dentary, right m3, right m2, right m1, right p4, right c1, right i3, right i2, left i1, left i2, left i3, left c1. Bottom row: horizontal ramus of right dentary (in two pieces), left dentary (in two pieces) with m1-m3.

Order Carnivora

Family Ursidae

Ursus americanus (American black bear)

Material. OMNH 73400 (Figs. 9, 10, 11), partial skeleton including the following elements: five of the upper teeth (left and right I3s, left and right C1s, and right P3), partial right dentary (in 3 pieces, poorly preserved), left i1, left and right i2s, left and right i3s, left and right c1s, right p4, right m1, right m2, right m3, and partial left dentary (in two pieces) with m1-m3, left humerus (missing proximal epiphysis), left ulna (missing distal end), right radius (missing proximal end), partial left radius (3 pieces of the shaft), nearly complete and articulated right manus, left ilium fragment, distal portion of baculum, left femur diaphysis and separate distal epiphysis, patella, left calcaneum, right astragalus and navicular (articulated), left and right cuboids, right ectocuneiform, left metatarsals III, IV, and V, several phalanges, and other fragments.

Discussion. All of the bones belong to one black bear skeleton and were recovered from Units 6 and 7. Based on the presence of a partial baculum, the individual is a male. The skeleton was partly disarticulated. Major limb elements and smaller teeth and bones were scattered, but the bones of one hand were mostly articulated, and several of the bones of one foot were partially articulated. Water transport of the bones before burial and exposure to flowing water during burial appears to have been minimal judging from the condition of the bones, which show little or no wear caused by water-transported sediment. However, the bone is poorly preserved and many elements are broken or soft and friable. The teeth are somewhat better preserved than the bone. Externally the tooth enamel is free of clinging matrix, while internally the dentin is chalky and friable. In places where small amounts of rock matrix had adhered to the enamel, portions of teeth were broken during preparation. The partial left dentary bone contains the m1-m3 but is broken anteriorly ahead of the m1 and posteriorly at the condyloid and angular processes; the dentary depth (in mm) on the labial side of the bone is 35.8 below the m1, 37.0 below the m2, and 39.9 below the m3. Measurements of the individual teeth are provided in Table 1. Widths of m1, m2, m3, and length of m3 of the CZ-9 Cave black bear are larger or near the large end of the observed range for modern black bears from Newfoundland, Alaska, New York, and California (Miller et al. 2009). However, compared to another study (Wolverton and Lyman 1998), length and width of the m3

Table 1. Measurements (in mm) of the teeth of a Pleistocene American black bear, OMNH 73400, from CZ-9 Cave, Cherokee County, Oklahoma.

Tooth	Anteroposterior diameter			er
	Left	Right	Left	Right
I3	12.0	11.8	8.7	7.9
C1	18.7	19.3	13.6	13.5
P3	---	5.0	---	4.0
i1	5.3	---	3.3	---
i2	7.0	7.3	4.7	5.1
i3	6.8	6.9	7.2	7.4
c1	19.1	18.8	12.8	12.8
p4	---	9.3	---	5.9
m1	21.0	20.8	9.6	9.7
m2	21.6	22.1	13.7	13.6
m3	15.4	15.9	12.6	12.5
m1-m3	57.1			

from CZ-9 Cave are somewhat above the averages but well within the observed ranges of these measurements for the same tooth in recent black bears from across the United States. In bears, tooth size is not strongly correlated with body size. The size of the CZ-9 black bear is not unusual.

Ontogenetic age of the bear. The skeleton represents a young adult based on the condition of the teeth and bones. All of the permanent teeth were in place, with no evidence of deciduous teeth, which black bears usually lose before reaching 1 year of age. The amount of wear on the canines and incisors indicates an ontogenetic age of at least 1-2 years (Heffelfinger 1997). The I3s are slightly worn at their apices; all lower incisors are worn on their apices. For all four canines, the permanent teeth are fully erupted and the pulp cavities of the canine roots are completely closed. The tips of the main cusps are unworn, but there are small contact wear facets where the upper and lower canines pass by one another (on the posterior surfaces of the lowers and on the anterior surfaces of the uppers). This interdental contact with the upper canine wore through the enamel to expose a small area of dentin on the posterior surface of the right lower canine, but not on the left. The P3 and p4 are not worn; the lower molars show small areas of exposed dentin especially on the more prominent cusps. In the available molars, there is sufficient wear on the enamel of the higher ridges and cusps on the m1s and m2s to expose very small areas of dentin, but the m3s show no exposed dentin. Among the postcranial bones, several long bones have partly fused or unfused epiphyses. These sutures were differentially weathered during burial, possibly enhancing their apparentness. In the humerus, the proximal epiphysis was unfused and is missing; the distal epiphysis is incompletely fused to the diaphysis. The right radius distal epiphysis is incompletely fused. All epiphyses of the left femur were completely unfused; the proximal ones (head and greater trochanter) are missing but the separate distal epiphysis was recovered. In the left calcaneum, the epiphysis on the tuber calcanei is incompletely fused. All of the epiphyses of the metapodials and phalanges of the manus and recovered bones of the pes are partly fused. In the right manus the distal epiphyseal line is indistinct on metacarpals I, II, and III; it is somewhat more

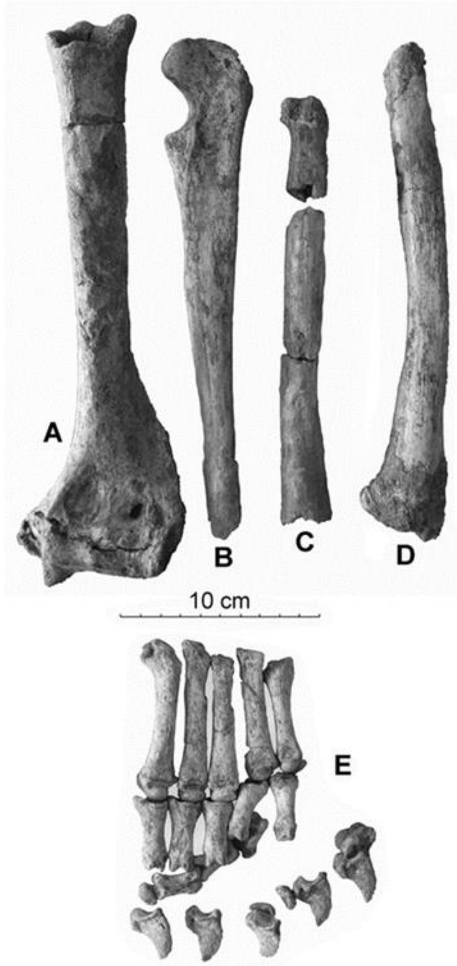

Figure 10. Black bear forelimb elements recovered from Cz-9 Cave. A, left humerus (anterior view); B, left ulna (medial view); C, left radius (anterior view); D, right radius (anterior view); and E, articulated manus, with bones shown in their relative positions as found (metacarpals and first phalanges in anterior view, ungual phalanges in lateral view, second phalanges and sesamoids somewhat scattered).

obvious on metacarpal IV and is quite distinct on metacarpal V. According to Marks and Erickson (1966), metacarpal fusion is complete in male black bears by age 1-2 years, but fusion of the radial epiphyses is not complete until 6-8 years. Marks and Erickson (1966) also note that the length of the baculum in male bears is correlated with age. However, the baculum from the CZ-9 Cave black bear is broken proximally and only 67 mm of the

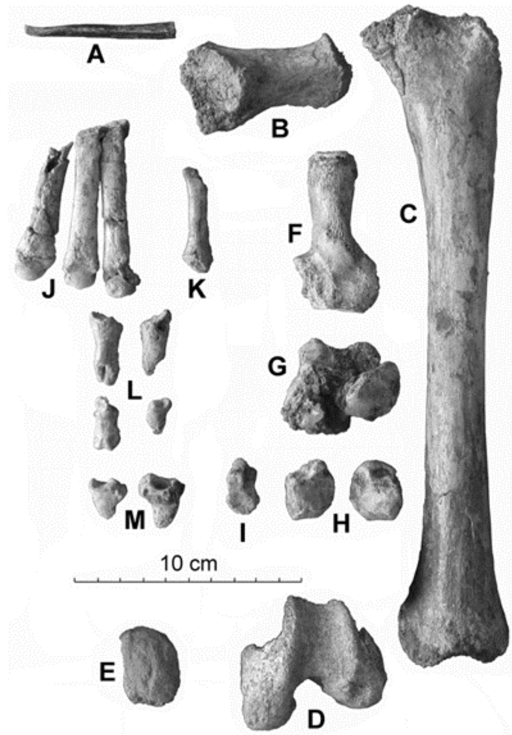

Figure 11. Black bear pelvis, baculum, and hind limb bones from Cz-9 Cave. A, distal portion of baculum (lateral view); B, left ilium (lateral view); C, left femur diaphysis (anterior view); D, left femur distal epiphysis (distal view); E, patella (anterior view); F, left calcaneum (proximal view); G, semi-articulated and partly concreted right astragalus and navicular (proximal view); H, left and right cuboids; I, right ectocuneiform; J, left metatarsals III, IV, and V (dorsal view); K, first(?) metatarsal or metacarpal (dorsal view); L, first and second phalanges (dorsal view); M, ungual phalanges (lateral views).

distal portion of the bone is preserved. Given this evidence, the CZ-9 Cave bear was probably between 1 and 2 years old when it died.

Discussion

Because bears often den in protected places such as caves, and because caves sometimes provide an environment favorable for burial and fossilization, the finding of a young black bear in CZ-9 Cave is not unexpected. Nevertheless, such records are not common in Oklahoma and the CZ-9 specimen serves as voucher for the occurrence of the species in

Oklahoma prior to their recent historical extermination and re-entry. Lee and Vaughan (2003) noted that in Virginia, 1- and 2-year-old male black bears were the sex and age-class likely to disperse; subadult females did not disperse in their study. Suitable dens are often reused by black bears (Alt 1984).

Black bears' genetics based on recent populations suggest a historical pattern in North America showing a long regional isolation that separated western from eastern forms beginning in the early Pleistocene, followed by hybridization upon re-contact after the last deglaciation (Wooding and Ward 1997). The isolation in part was probably related to the glacial separation of western from eastern forests that would have been occupied by the bears. The occurrence of a black bear in CZ-9 Cave at 10,958 ± 35 rybp (= 12,959 to 12,654 ybp calibrated date with 95% confidence interval), during the last deglaciation, suggests the species' continued presence in a late Pleistocene forest refugium in the Ozark Highland during the last glacial period, or else indicates a rapid recolonization of the Ozarks from forests farther east or north.

Numerous records of short-tailed shrews exist from the late Pleistocene (late Wisconsinan glacial period) through the Holocene of North America (Graham and Lundelius 2010) as well as earlier fossil species in the Pliocene and early Pleistocene (Hibbard 1957, Repenning 1967). Although historically most Quaternary fossils of short-tailed shrews have been identified in the literature as *Blarina brevicauda*, George (2012) showed that phylogenetically important characters do not support these species identifications. Because of the difficulty of identifying scrappy remains of recently-differentiated and closely-related species of shrews and other small mammals, most of these Pleistocene remains are likely identifiable to genus *Blarina* only.

In recent historic times, the species now known as Elliot's short-tailed shrew, *B. hylophaga*, is the species of *Blarina* occupying northeastern Oklahoma (Brant and Orti 2002) as well as the eastern half of Oklahoma (Caire et al. 1989) and parts of adjacent states. The small-bodied species *B. carolinensis*, the southern short-tailed shrew, today occurs in the extreme southeastern corner of Oklahoma, as well as adjoining parts of Texas, Arkansas, and eastward. Northern short-tailed shrews, *B. brevicauda*, occur today from south-central Canada to the mid-latitudes of the eastern United States (Wilson and Ruff 1999). This large-bodied species today is found north of the Platte River, Nebraska, and in eastern Missouri (Brant and Orti 2002, Reid 2006). As noted above, Sherman's short-tailed shrew, *B. shermani*, occurs only in a small area of Florida.

Like the CZ-9 shrews, some Pleistocene fossil shrews were larger than modern ones of the same geographic areas (e.g., Schubert 2003). This phenomenon caused Hibbard (1943) initially to nominate a species *Blarina fossilis* but later to relegate this extinct taxon to a subspecies *B. brevicauda fossilis* (Hibbard 1957). Rapid changes in climate, like that of the last deglaciation between about 12,000 and 10,000 rybp, can cause rapid shifts in the geographic ranges and contribute to the speciation and extinction of species (e.g., Blois and Hadly 2009, Chen et al. 2011, Schloss et al. 2012, Semken et al. 2010). Short-tailed shrew body size probably changed dynamically across eastern North America as climate, environmental conditions, and geographic ranges of shrew populations changed during the Pliocene, Pleistocene and Holocene, ultimately resulting in the differentiation of the modern named forms. Because the fossils from CZ-9 Cave are of large body size and are probably near the same geologic age as the black bear fossils (late Pleistocene), they provide evidence of this change in the species and body size of *Blarina* inhabiting the Oklahoma Ozarks since the time of deposition of the CZ-9 Cave sediments and fossils, even if they cannot be assigned to a species.

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