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NEW RECORDS OF HARLAN'S MUSKOX (*Bootherium bombifrons*) AND AN ASSOCIATED FAUNA FROM THE LATE PLEISTOCENE OF INDIANA

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ABSTRACT: Remains of at least six individuals of Harlan's muskox (*Bootherium bombifrons* = *Symbos cavifrons*) are reported from five Indiana localities. One partial male cranium was discovered in 1938 during water main construction in Muncie, Delaware County, but only recently has been acquired for the State Museum collection. Another partial male cranium was recovered in 1987 from a Madison County peat deposit. Sand and gravel pits in Clark and Gibson counties produced the only two portions of female skulls known from Indiana. Associated remains of two individuals, consisting of isolated teeth, podial elements, and fragments of various other elements were found deep within King Leo Pit Cave, Harrison County, approximately 77 m from an old entrance that is now closed. The microfauna associated with the King Leo muskoxen contains at least twenty-six taxa, including such northern species as the heather vole (*Phenacomys intermedius*), southern red-backed vole (*Clethrionomys gapperi*), and fisher (*Martes pennanti*), and suggests the presence of boreal conifer forest interspersed with more open areas during deposition of the faunal remains in the cave.

INTRODUCTION

The number of late Pleistocene muskox fossils in Indiana is exceeded only by those of mastodons and mammoths, among the larger mammals. Muskox specimens consisting largely of cranial material and once thought to represent two or three species have been reported previously for approximately twenty Indiana localities (Richards, and Wepler, 1985). One Wayne County cranium represents the modern muskox *Ovibos moschatus* (Baker, 1920; Hay, 1912, 1923; Lyon, 1926, 1936). A Newton County specimen identified as "*Bootherium*" (Baker, 1920; Bradley, 1870; Hay, 1912, 1923; Lyon, 1936) cannot be located. Insufficient information was recorded in the published description to substantiate the generic assignment. A single Gibson County, Indiana specimen, with relatively rounded horn cores, and lacking the notable pitted, bony exostosis between the horn cores characteristic of *Symbos cavifrons*, had been referred to *Bootherium* (USNM 24885; information and casts sent to Indiana State Museum by Robert W. Purdy, Dept. of Paleobiology, U.S. National Museum, March 1984). All other crania of muskoxen from Indiana that displayed exostoses across the dorsal surface of the cranium and dorsoventrally flattened horncores previously have been referred to *Symbos cavifrons*. These include specimens from Bartholomew (Allen, 1913; Baker, 1920; Hay, 1912, 1923; Lyon, 1936), Kosciusko (McDonald, and Ray, 1989a), LaGrange (Rarick, and Wayne, 1969), LaPorte (Lyon, 1931, 1936), Miami (2 localities:

Lyon, 1936; Richards, and Wepler, 1985), Montgomery (Lyon, 1942; Lyon, and Hall, 1937), Owen (Lyon, 1942), Porter (Allen, 1913; Baker, 1920; Hay, 1912, 1914, 1923; Lyon, 1936; Moodie, 1929), Randolph (Hay, 1912, 1923; Lyon, 1936; Moodie, 1929), and St. Joseph (Engels, 1933; Lyon, 1926, 1936) counties. A recent review of the autochthonous North American muskoxen (McDonald, and Ray, 1989a) concluded that *Bootherium* and *Symbos* represented sexually dimorphic forms of a single species for which the name *Bootherium bombifrons* (Harlan) 1825 has priority. Therefore, all generically or specifically identifiable fossil muskoxen now known from Indiana (except *Ovibos*) are referred either to the female (Gibson County) or males (all other crania) of *Bootherium bombifrons*. Several other muskox crania (from Knox, Marion, and Park counties) under study by Patrick Munson and Russell Graham are males of *Bootherium bombifrons* (pers. comm. Munson to Richards 17 November 1989).

Muskox remains have been recovered from the northern two thirds, and the southwestern corners of Indiana. No specimens have been reported in the literature from the south central or southeastern portions of the state.

Records of *Bootherium bombifrons* have been found across much of North America from Alaska to Mississippi and from British Columbia and California to the Atlantic continental shelf (McDonald, and Ray, 1989a). Fossils of *Ovibos moschatus* seldom are found far south of the Wisconsinan terminal moraine or far from the lower Cordilleran moraines (Kitts, 1953; McDonald, and Davis, 1989). Pollen associated with several *Bootherium* specimens suggests "that the extinct muskox occupied a geographically extensive niche" (Skwara, and Walker, 1989) and "appears to have been a feeding generalist. Pollen spectra associated with specimens...indicate that it occupied habitats ranging from herbaceous tundra and boreal-like forests to mixed and deciduous woodland" (McDonald, and Ray, 1989b). The pollen assemblage recovered from the gastrointestinal tract of a mummified carcass of a female *Bootherium* found along Fairbanks Creek, Alaska, contained large proportions of Gramineae and *Artemisia* pollen and suggested that the individual died during mid- to late-summer in an herbaceous tundra (McDonald, 1984; McDonald, and Ager, 1985). Pollen from the cranial cavity of the Scotts, Kalamazoo County, Michigan specimen was dominated by pine (*Pinus*), with lesser amounts of oak (*Quercus*), followed by spruce (*Picea*), balsam fir (*Abies*), larch (*Larix*), and birch (Betulaceae), radiocarbon dated at 11,100 ± 400 BP (Semken, *et al.*, 1964). Undated pollen from muds within the White Pigeon cranium, St. Joseph County, Michigan, consisted predominantly of *Picea*, with lesser amounts of *Quercus*, *Pinus*, and *Larix* (Semken, *et al.*, 1964). Pollen associated with *Bootherium* vertebrae from Climax, Kalamazoo County, Michigan and radiocarbon dated at 13,200 ± 600 BP indicated spruce forest in the area of deposition (Benninghoff, and Hibbard, 1961; Hibbard, and Hinds, 1960).

Tree pollen from sediments within a muskox cranium from Saltville, Smyth County, Virginia was dominated by *Pinus* and *Picea*, the entire spectrum suggesting a spruce parkland interspersed with marshes, ponds, and prairies (Ray, *et al.*, 1967). More recent investigations of the pollen spectrum for Saltville Valley indicate that *Picea* and *Pinus* pollen, while dominant among arboreal taxa around 13,500 BP, waned while pollen of broadleafed deciduous trees, especially *Quercus*, became relatively more abundant during the last three millenia of the Wisconsinan glaciation (Delcourt, and Delcourt, 1986). Remains of *Bootherium bombifrons* are known from throughout much of the period 13,500 - 10,000 B.P. at Saltville during which time the vegetation of the region is

envisioned as having been mosaic-like at any given time, with the taxonomic composition of communities changing through time (McDonald, unpub. data; McDonald, in press).

There have been several difficulties in understanding the paleobiology of *Bootherium*. Most of the ten radiocarbon dates produced from *Bootherium* bone or tissue have been from specimens found in western North America (Alaska, range of seven dates: 17,210 ± 500 B.P. - >40,000 B.P.; Colorado, 15,970 ± 155 B.P.; Michigan, 13,200 ± 600 B.P., 11,100 ± 400 B.P. (McDonald, and Ray, 1989a). Even though many specimens have been recovered in bog and kettle lake contexts in the eastern United States, few studies of the associated pollen spectra have been undertaken. Microvertebrate remains of environmentally sensitive microtine rodents and shrews are rarely associated or recovered with *Bootherium* fossils. Finally, there is a general dearth of *Bootherium* postcranial material in museums with which to identify isolated elements of recovered fossil ovibovines.

SPECIMEN CONTEXT AND DESCRIPTION

The authors recently have been able to study previously unreported *Bootherium bombifrons* fossils from Delaware, Madison, Clark and Harrison counties, Indiana and to describe a previously cited Gibson county specimen. Abbreviations used in this report: INSM, Indiana State Museum, Indianapolis; USNM, National Museum of Natural History, Washington, D.C.; L, R, left, right; I, P, M, upper incisor, premolar, and molar, respectively; i, p, m, lower teeth; w. with (listed teeth); MNI, minimum number of individuals; B.P., before present (1950 A.D.).

LOCALITY #1: Muncie, Delaware County, Indiana. MATERIALS/DESCRIPTION: *Bootherium bombifrons* (male): incomplete skull (Figure 1). The solid, heavy skull consists of the entire occiput and braincase with cribriform plate in position, the dorsal part of the cranium with complete horncores, and the right orbital area with zygomatic arch. Lacking are the nasals, the left jugal, much of the left sphenoid, part of the left lacrimal, the palate, and all of the teeth. The horn cores are relatively flat on their dorsal, and convex on their ventral, surfaces. Longitudinal grooves occur on the ventral surfaces of the horn cores. The roughened exostosis covers much of the dorsal surface of the frontals and parietals, and forms a slight (up to 10 mm high) longitudinal crest in the anterior portion of the intercornual trough. The intercornual trough is widest at the middle of the horncores. Exostotic bone does not extend onto the horn cores. Many of the sutures are closed. Both lacrimal fossae are apparent. The basioccipital posesses the median groove and "V" shaped "shield" described by McDonald (1985b). The parieto-temporal suture is oriented horizontally. The skull retains much of its natural surface detail and is unabraded and ungnawed. Measurements are presented in Table 1. PROVENIENCE: Discovered around 1938 by construction workers laying a water main under Main Street, Muncie. The city is built upon mixed till and stratified drift that appear to have been deposited in subice tunnels and ice-walled channels of the Huron-Erie lobe of Wisconsinan ice (Gray, 1989). These mixed deposits occur just south of, and appear to be related to, drainage beyond the Union City Moraine, believed to have formed around 15,500 B.P. (Mickelson, *et al.*, 1983). COMMENTS: Upon discovery the skull was given to Dr. Roland Bunch, the mayor of Muncie. It was later acquired by Mr. Ben W. Thompson, Kirkwood, Missouri, and in 1968 was purchased by Gary J. Sawyer, Director of Collections, for The Natural History and Science Museum, Blairstown, New Jersey. The skull was purchased for the Indiana State Museum

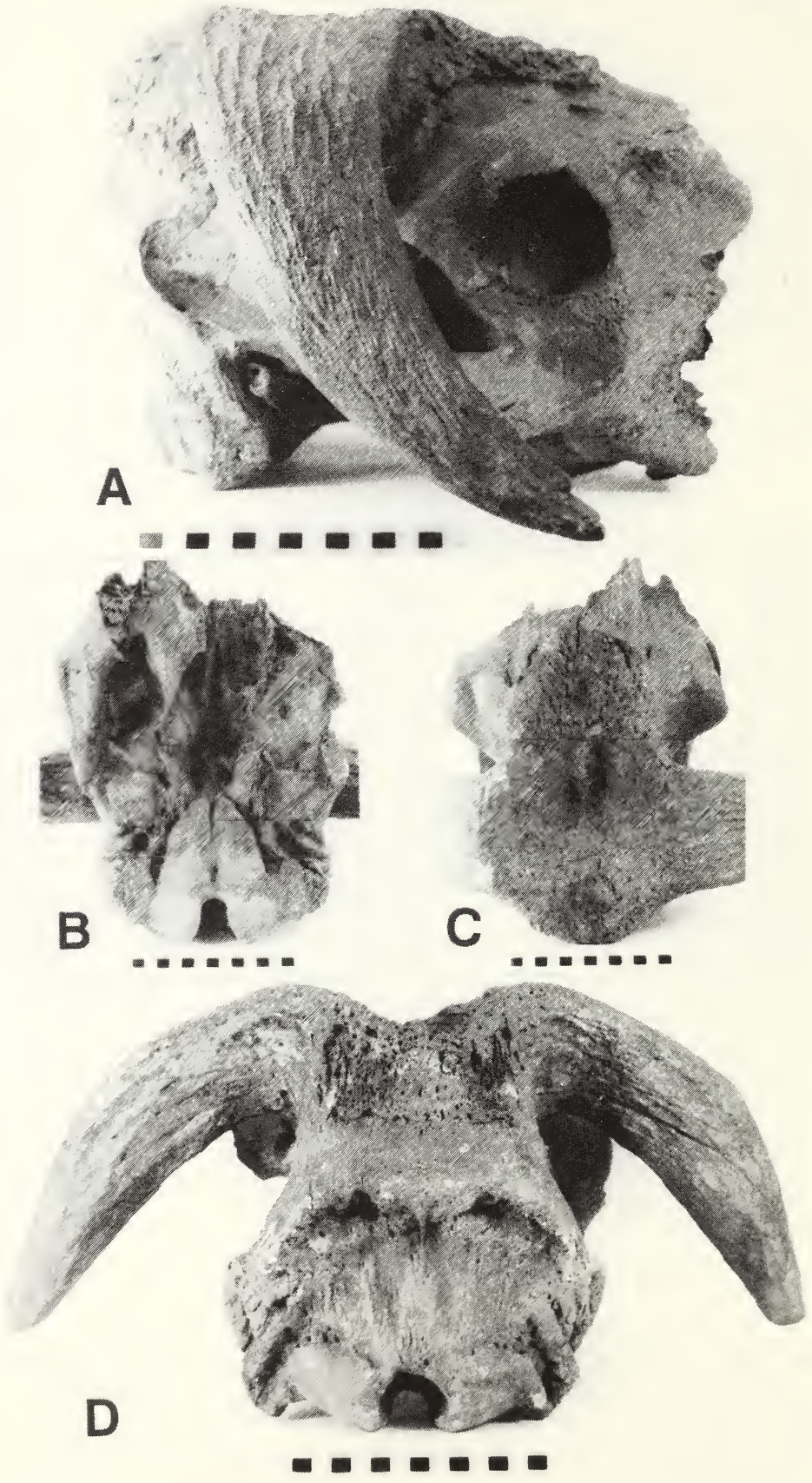

Figure 1. *Bootherium bombifrons* (male), Muncie, Delaware County, Indiana. A, Right lateral view. B, Ventral view, showing groove and "shield" morphology of basioccipital. C, Dorsal view, showing exostosis. D, Occipital view. Scale in centimeters.

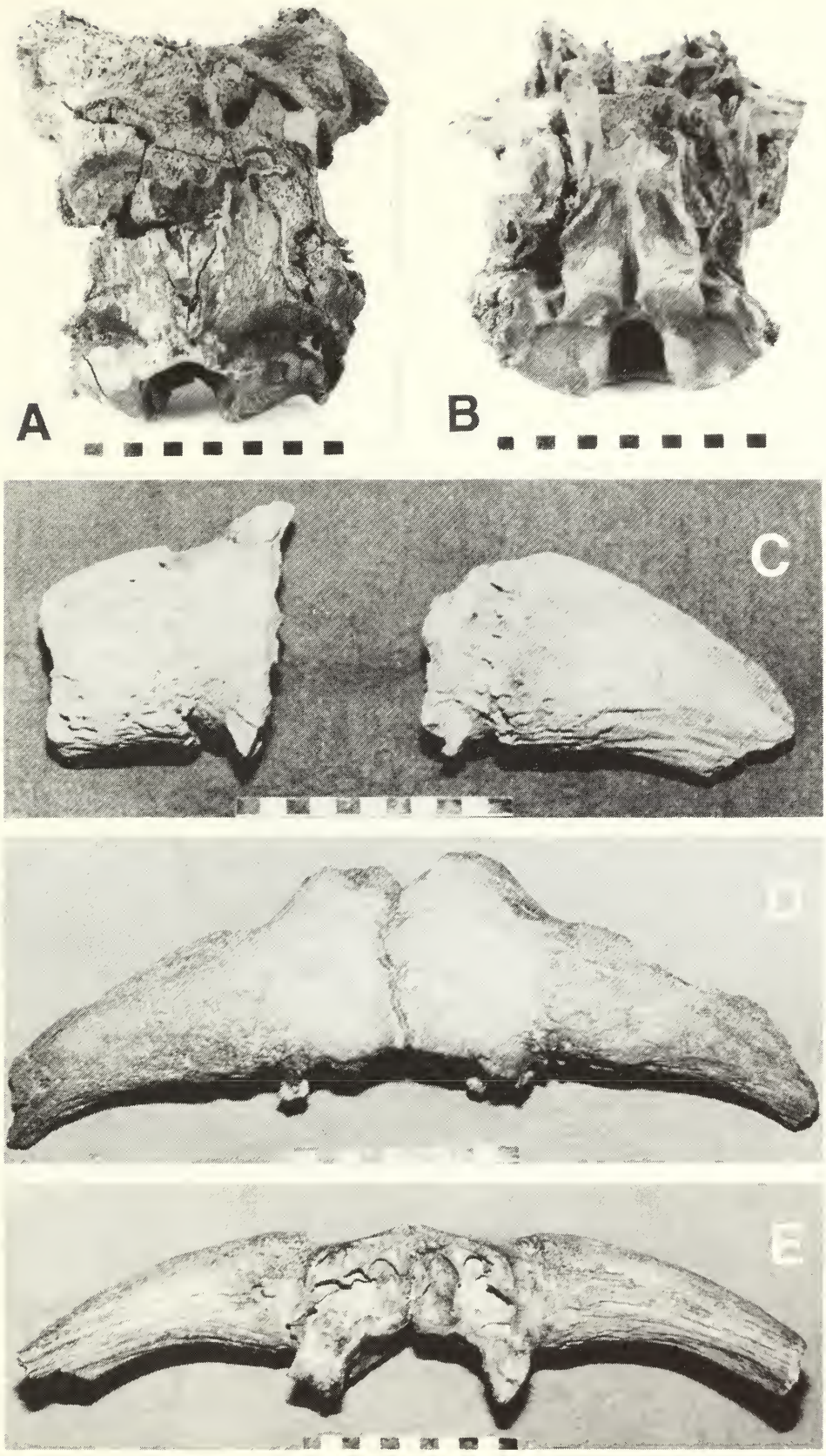

Figure 2. Indiana *Bootherium bombifrons*. A-B: Male skull portion, Madison county, Indiana. A, Occipital view. B, Ventral view, showing groove and "shield" morphology of basioccipital. C. Female horn cores, Clark county (dorsal view). D-E: Cast of female skull roof with horn cores, Gibson county. D. Dorsal view (note lack of exostosis). E. Anterior view. Scale in centimeters.

(INSM) in 1989, and now bears the catalogue number 71.3.70. At one time coated with a dark (?) varnish, the skull has recently been consolidated with glyptal, driven by acetone.

LOCALITY #2: Madison County, Indiana. The owner of the deposit would like for the specific locality to be kept confidential. MATERIALS/DESCRIPTION: *Bootherium bombifrons* (male): Partial skull (Figure 2A-B); lumbar vertebra. This extensively leached skull consists of most of the cranium caudal to the orbits. All but the bases of both horn cores are missing, as is the entire face, the left squamosal and both zygomatic processes. Part of the cribriform plate is present. The skull is extensively disintegrated, and fragments of the exostosis spall off readily. The remaining exostosis appears very thin over the frontals and parietals. A small section of the frontal suture is visible in an exfoliated area. All sutures are not fused, and the left petrosal has detatched from the temporal. Several chunks are missing from the occiput, apparently due to damage by earth-moving equipment at the time of discovery. This damage includes the breaking away of most of the nuchal line, but the attachment for the nuchal ligament and the insertion surface for the right *M. semispinalis capitis* are recognizable. The basioccipital is well preserved, and displays the groove and "shield" morphology referred to above. The parieto-temporal suture is horizontal. The skull appears "weathered", and may have disintegrated where it lay in the peat deposit. There is no suggestion of stream transport. The lumbar vertebra lacks the lateral processes and neural spine. It represents a mature, relatively small ovibovine, possibly a female *Bootherium bombifrons*. Measurements are presented in Table 1. PROVENIENCE: The skull and vertebra were discovered lying approximately 4 m apart on the surface during the removal of peat by heavy equipment in 1987. The peat also contained wood and conifer cones. The peat deposit formed in a relict drainageway of the Huron-Erie lobe of Wisconsinan ice. The drainage system was entrenched into till of the Trafalger formation that had been deposited sometime after 21,000 B.P. (Fraser, *et al.*, 1983). The Union City Moraine, formed around 15,500 B.P. (Mickelson, *et al.*, 1983), transects the northeast corner of the county, to the north of the site. COMMENTS: The skull and vertebra, consolidated in glyptal driven by acetone, are reposited at Mounds State Park, east of Anderson, Indiana.

LOCALITY #3: Gibson county, Indiana (ca. 4 miles southeast of Mt. Carmel, Illinois). MATERIALS/DESCRIPTION: *Bootherium bombifrons* (female): skull frontals with portions of both horn cores (Figure 2D-E); L frontal fragment; occipital; L metacarpal III + IV. Descriptions and measurements are taken from casts on file at the INSM (catalogue number 71.3.22). The frontals include 151 mm of the left, and 156 mm of the right, horn cores (length from burr). The small size of the specimen and fracture along the interfrontal suture suggest that a subadult individual is represented. The horn cores are rounded at the bases, possess distinct burrs, and curve downward, characters that indicate a female *Bootherium bombifrons* (McDonald, and Ray, 1989a). The horn cores measure 62.2 mm (L) and 62.3 mm (R) rostrocaudally, and 56.3 mm (L) and 58.1 mm (R) dorsoventrally, at the burr line; they measure 191.5 mm (L) and 191 mm (R) in circumference at the same position. Much of the occiput is present, including basioccipital and supraoccipital portions, and the foramen magnum, with the left, and much of the right, occipital condyles. The metacarpal is complete, providing the following measurements (mm): greatest length (GL): 268.5; greatest proximal breadth (Bp): 64.3; greatest distal breadth (Bd): 77.7; smallest breadth of diaphysis (SD): 43.9.

Table 1. *Bootherium bombifrons*, Selected Measurements (mm).

Cranial Measurements[1]	Delaware Co.	Madison Co.
Exostosis length:	271	
Exostosis width, anterior to horncores**:	134	
Exostosis width, across anteroinferior flanges:	169	
Greatest depth of intercornual trough:	49.4	42*
Tip of horn core to sagittal plane:	L = 276.5 R = 277	
Width between horncore tips (43):	554	
Circumference of horncore base**:	L = 305 R = 324	L = 292*
Greatest rostrocaudal length of horncore base**:	L = 112 R = 118	L = 106
Greatest dorsoventral diameter of horncore base**:	L = 80 R = 83	L = 78
Neurocranium length: nasion-basion (6):	291	
Median frontal length: nasion - midpoint of nuchal line (8):	295	
Width of frontal at constriction between horncores and orbits (32):	150	ca. 140
Greatest breadth across the orbits (33):	264	
Greatest breadth across jugals, below orbits: est	150	
Face width between frontal foramina:	103	
Width of cranium at constriction above nuchal line:	141	135
Mastoid breadth (25):	216	
Greatest breadth, occipital condyles, primary (26):	141 est	148
Greatest breadth, occipital condyles, with auxillary surface:	152	
Greatest breadth at bases of paraoccipital processes (27):	195	
Greatest breadth of basioccipital:	92.6	
Height from ventral margin of occipital condyle to plane of dorsal surface of horn cores:	249 est	215
Height from basion to floor of intercornual trough:	210	187*
Greastest height of occipital region: basion-nuchal line:	142 est.	131*
Minimum height of occipital: opisthion-nuchal line:	109 est.	107*
Height, opisthion to dorsal edge of nuchal ligament insertion:	83	76.2
Height of foramen magnum (29):	41.4	44.7
Breadth of foramen magnum (28):	39.4	46.4
Angle: foramen magnum plane with occipital plane:	117°	128°
Angle: foramen magnum plane with basioccipital plane:	149°	148°
Greastest length of orbit (23):	L = 67	
Greastest height of orbit (24):	L = 61	

Measurements of teeth	King Leo Pit Cave, Harrison County	
Tooth	Length at neck	Breadth at neck[3]
LP4	19.1	24.3
RP4	19.8	21.7
RP4	(20.6)	24.2
RM1	——	25.6
RM2	(30.4)	(28.0)
RM3	41.8	(27.8)

i, undifferientiated	8.2	10.9
i, undifferientiated	9.2	12.1
i, undifferientiated	9.4	11.9
i, undifferientiated	10.4	11.9
Lp2	12.2	11.5
Rp2	12.5	11.6
Lp3	19.6	(14.6)
Lm1	26.2	(17.9)
Lm2	(31.2)	(22.2)
Rm2	30.2	(24.1)
Rm3	52.1	(22.0)

Postcranial Measurements[2]		King Leo Pit Cave, Harrison County		
Carpal 2 + 3	Greatest breadth(GB)	49.6		
	Greatest length(GL)	40.9		
Malleolar bone:	Greatest depth(GD)	38.1		
Proximal sesamoids:	Greatest breadth(GB)	15.2	19.4	16.6
	Greatest length(GL)	25.9	26.0	28.1
Distal sesamoids:	Greatest breadth(GB)	33.7	30.4	
Proximal phalanx:	Greatest length(GL)	80.6		
	Smallest breadth of the diaphysis(SD)	28.2		
	Greatest breadth of the distal end(Bd)	33.7		
Second phalanx:	Smallest breadth of the diaphysis(SD)	24.6		
	Greatest breadth of the distal end(Bd)	28.8		
Distal phalanx:	Length of the dorsal surface(Ld)	72.2	88.3	
	Greatest diagonal length of sole (DLS)	——	71.9	

Lumbar vertebra measurements[2]	Madison County
Length, at body center (PL)	63.0
Greatest length, at articular processes (GLPa)	94.0
Greatest breadth, cranial articular surface (BFcr)	47.1
Greatest breadth, caudal articular surface (BFcd)	53.0
Minimum breadth between transverse processes and cranial articular surfaces	43.1
Greatest breadth, cranial articular process (BPacr)	66.8
Greatest breadth, caudal articular process (BPacd)	42.8
Breadth, vertebral foramen, cranial end	34.6
Height, vertebral foramen, cranial end	21.8

[1] Measurements primarily after McDonald (1985a, 1985b), Harington (1975), Semken, *et al.* (1964), and von den Driesch (1976); numbers in parentheses refer to measurements illustrated in von den Driesch; * Fragmented area; **Calipers difficult to position along curving contours of skull.

[2] Measurements as in von den Driesch (1976).

[3] Breadth at neck: anterior cusp in molars; greatest breadth in premolars and incisors.

PROVENIENCE: Recovered at a depth of 5-20 feet, in a gravel pit. Although the exact locality has not yet been determined, major sand and gravel deposits in that portion of Gibson county consist primarily of Wisconsinan valley train deposited along the Wabash River sluiceway. COMMENTS: Recovered by a farmer from a local gravel pit in the fall of 1965, the bones were turned over to a farm advisor, who in turn forwarded them to a University of Illinois archaeologist for identification. The bones were then referred to P.W. Parmalee, Illinois State Museum, who sought the council of C.E. Ray, U.S. National Museum (letters: Parmalee to Ray, 3 December 1965, 17 December 1965; Ray to Parmalee, 15 December 1965, 23 February 1966). The fragile bones, preserved by impregnation with wax, are housed in the USNM under catalogue number 24885. Casts are also on file at the Indiana State Museum (catalogue number 71.3.22), and the Illinois State Museum. Although the Gibson county record has been cited by Richards and Wepler (1985) and McDonald and Ray (1989), the present is the only report to describe, illustrate, give measurements, and treat the geological context of the specimens.

LOCALITY #4: Silver Creek Sand and Gravel Company Quarry, Clarksville, Clark county, Indiana. MATERIALS/DESCRIPTION: *Bootherium bombifrons* (female): L and R partial horn cores (Figure 2C). Approximately 144 mm of the left and 67 mm of the right horn cores are preserved, attached to portions of the frontals. Sinus cells are well developed in the frontal portions of the horn cores, but the broken shafts reveal cancellous bone and occasional foramina in cross section. The horn cores are rounded at the bases, curve downward, and possess a distinct burr that is perforated ventrally by foramina. The pedicles are shorter than those in *Bison*. Details of the Clarksville fossils compare well with those of the Gibson county specimen (cast), though the Clarksville female represents a much larger individual. The Clarksville horn cores measure 76.3 mm (L) and 78.1 mm (R) rostrocaudally, and 72.5 mm (L) and 71.4 mm (R) dorsoventrally at the burr. They have nearly the same circumference (L = 238 mm; R = 237.5 mm). PROVENIENCE: The horn cores were discovered in 1987 among the gravel and cobbles that had been processed through a commercial sorter. Although the specimens are thought to have come from sands, their exact placement within the sand and gravel deposit is uncertain. Remains of two or three mammoths (*Mammuthus* sp.) had been recovered from sands and gravels of the same quarry between 1987 and 1989 (Richards, unpubl.). The deposit is one of many valley train, glacial outwash deposits of Wisconsinan age along the Ohio River in Indiana. COMMENTS: Catalogued as INSM 71.3.80, the remains were consolidated in glyptal, driven by acetone.

LOCALITY #5: King Leo Pit Cave, Harrison County, Indiana. MATERIALS/DESCRIPTION: *Bootherium bombifrons*: teeth and postcranial elements (Figure 3) representing two individuals. Elements include: LP4; 2RP4; RM1; RM2; RM3; LM frag; 4i; L, Rp2; Lp3; Lm1; L,Rm2; Rm3; cervical vertebra, transverse process; cervical vertebra, portion of body; manubrium, posterior portion; humerus, fragments of major tubercle and of distal condyle; L ulna, proximal fragment; R radius, proximal end fragment; fused second and third L carpal; L fourth carpal; R centroquartal, partial; 2 femora heads; femur, distal articular surface fragment; R tibia, fragment of body; R tibia, proximal articular fragment; R malleolus; R calcaneum, partial; metapodial, distal condyle; 1 partial, 1 complete proximal phalanges; 2 partial, 1 complete medial phalanges; 2 distal phalanges, partial; 3 proximal sesamoids; 2 distal sesamoids; 1 sesamoid, partial. The presence of two individuals is confirmed by two RP4's, and by the different

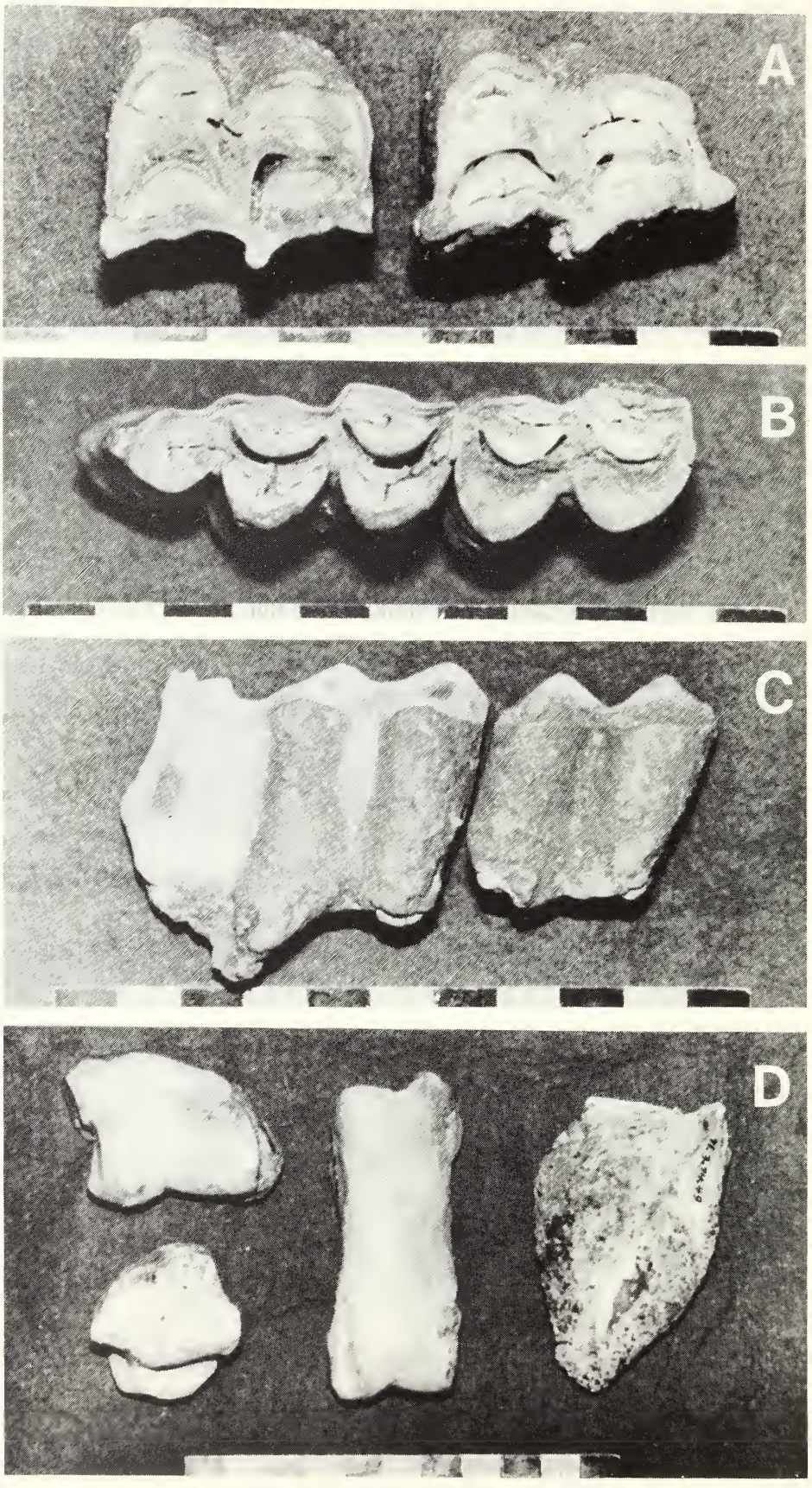

Figure 3. *Bootherium bombifrons* (sex unknown), King Leo Pit Cave, Harrison County, Indiana. A. Occlusal view, upper R molar 2 (left) and 3. B. Occlusal view, lower R molar 2 (right) and 3. C. Labial view of same (note encrusting cave "flowstone"). D. Foot elements: L carpal 2 + 3 (upper left), L carpal 4 (lower left), First phalanx (center), Third phalanx (right). Scale in centimeters.

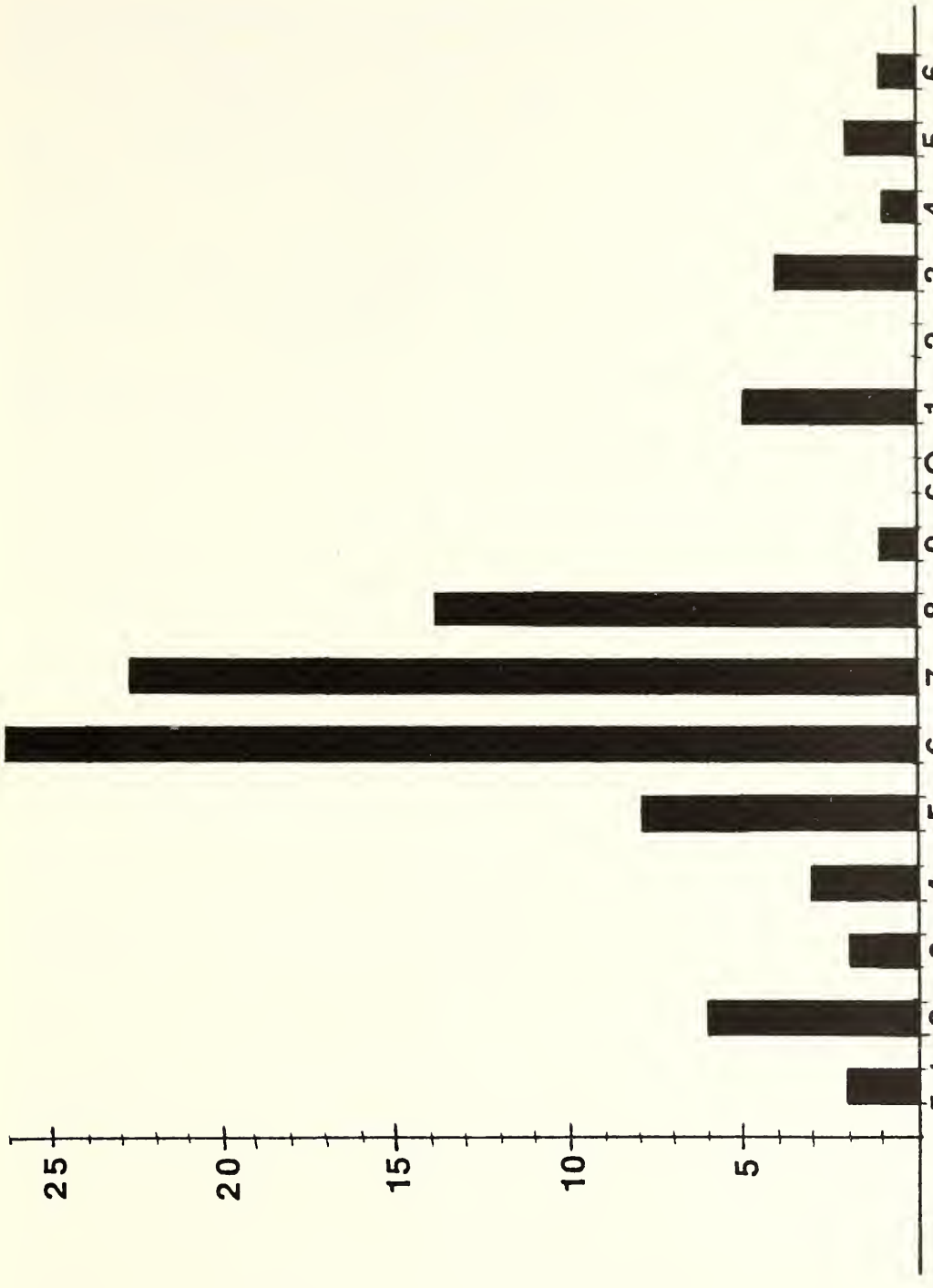

Figure 4. *Myotis* sp., King Leo Pit Cave, Harrison County, Indiana, alveolar length of dentaries (mm). Distribution indicates *Myotis* cf. *M. leibii* (mode 5.2), *Myotis* cf. *M. lucifugus/sodalis/austroriparius* (mode 5.6), and *Myotis* cf. *M. keeni/grisescens* (range 6.1-6.6).

Table 2. Faunal remains from *Bootherium* locus, King Leo Pit Cave, Harrison County, Indiana

Taxa	MNI	Materials
Fish, sp. indet.	1	2 Vertebral centra; opercular fragment
Eurycea lucifuga, Cave salamander	1	3 complete, 1 fragmented vertebrae
Colubridae cf. *Lampropeltis/Elaphe* sp., milk snake/rat snake	1	3 trunk vertebrae
Snake, sp. indet.	1	2 fragmentary vertebrae; 3 ribs
Blarina brevicauda, Northern short-tailed shrew	2	Fragmented R dentary (w. i,m1) L, R maxilla frags.; RI; 2RP4; IL, 2RM1.
Cryptotis parva, Least shrew	1	Palate w. LP4, RP4-M2
Sorex cinereus, Masked shrew	1	L dentary (w. i,m1,m2)
Sorex cf. *S. fumeus*, Smokey shrew	2	L dentary (w. i,m1); Li; R dentary (w. m2,m3); R dentary (w.m1); L maxilla (w. P4)
Sorex hoyi, *Pygmy shrew*	1	L dentary (w.i, m1)
Sorex, small sp.	2	2L, 1R dentary portions
Myotis cf. *M. keeni/grisescens*, Keen's myotis, and/or gray bat	9	4L, 9R dentaries
Myotis cf. *M. leibii*, Small-footed myotis	6	4L, 6R dentaries
Myotis cf. *M. lucifugus/sodalis/austroriparius*, Little brown bat, Indiana bat, and/or southeastern myotis	39	39L, 37R dentaries
Myotis sp., Mouse-eared bats	201	188L, 203R dentaries; 53L, 28R maxillae
Pipistrellus subflavus, Eastern pipistrelle	3	3L, 3R dentaries; palate
Plecotus sp., Big-eared bats	28	28L, 15R dentaries; palate; 2L, 5R maxillae
Bat, sp. indet.	68	88L, 81R dentaries; 72L, 68R maxillae
Martes pennanti, Fisher	1	Incomplete skeleton (Richards, 1989)
Glaucomys sp., New World flying squirrels	1	RP4; RM1
Sciurus sp., Tree squirrels	1	L,RI
Tamiasciurus hudsonicus, Red squirrel	1	L,R scapula portions; R ulna; L femur; R femur, prox. end; L innominate portion; L tibia shaft; L tibia, distal end
Sciurus/Tamiasciurus, Tree and/or red squirrel	1	1L, 3Ri
Peromyscus cf. *P. leucopus*, White-footed mouse	2	2 Lm1
Peromyscus cf. *P. maniculatus*, Deer mouse	11	10L, 11R m1; 3L, 5R dentaries
Peromyscus sp., Deer, and/or white-footed mice	8	8L, 7R m1; 9L, 14R dentaries; 8L, 10R maxillae
Clethrionomys gapperi, Southern red-backed vole	2	16 cheek teeth (Richards, 1986); additional RM3.
Microtus pennsylvanicus, Meadow vole	1	LM2; RM3; Lm1
Microtus cf. *M. ochrogaster*, Prairie vole	3	2L, 3Rm1
Microtus cf. *M. pinetorum*, Pine vole	1	L, R m1
Phenacomys intermedius, Heather vole	2	9 cheek teeth (Richards, 1986)
Mouse, sp. indet.	17	47L, 46R I; 40L, 28R i
Leporidae, *Sylvilagus* sp. and/or *Lepus* sp., Cottontail and/or hare	2	R dentary w. all teeth; Li; 2L, 3R lower cheek teeth; L, RI; 6L, 6R upper cheek teeth; frag. L maxilla, basicoccipital, atlas, axis, cervical and thoracic vertebrae, distal phalange.

sizes of medial phalanges and possibly of the sesamoids. Tooth wear indicates full adult individuals. Measurements are presented in Table 1.

PROVENIENCE: The remains of these muskoxen were brought to the senior author's attention by Mr. Richard Blenz, Bloomington Indiana Grotto of the National Speleological Society in October 1976. The bones occurred approximately 267 m from the present 14.3 m deep pit entrance. The deposit is accessible only through a narrow 73 m long crawlway that leads to a large open breakdown-strewn walking passage. The actual bone site is on the passage floor 77 m from a probable old entrance, now closed, that truncates near an above-ground ravine. This former entrance once likely provided access for the muskoxen or their remains. The *Bootherium* remains were, for the most part, unburied and consequently disintegrated on top of the cave floor silts. Many smaller elements, however, were buried and better preserved. Some items (eg. a second phalanx) were rodent gnawed. On at least two occasions cavers removed teeth from the site. The sediments consisted of approximately 10-20 cm of silt upon a ca. 4 mm thick travertine crust that covered a thin layer of silt that lay upon bedrock. Muskox bone scrap (591 gm) produced too little collagen to be reliable for radiocarbon dating (Beta-38724).

ASSOCIATED FAUNA: The associated fauna is listed in TABLE 2. The remains were recovered by washing ca .34 m^3 (38 gal.) of sediment through 1.2 mm mesh hardware cloth. Identifying characters for the uncommonly recovered or difficult-to-identify taxa are reviewed. Davis (1973) reviewed the methods of separating the similar vertebrae of *Eurycea* and *Plethodon*. In addition to those characters, trunk vertebrae of adult *Eurycea lucifuga* have an ossified, concave "plug" in the anterior end of the centrum, as well as sub-centrum ridges and a faint terminal spur on the posterior part of the centrum, not present in *Plethodon*. *Eurycea lucifuga* has a small, triangular dorsal spine, while that of *E. longicauda* is longer and more sail-like. Lower incisors of *Sorex cinereus* can be separated from those of the similar *S. longirostris* in that *cinereus* has a longer incisor with all three accessory tines strongly developed and pigmented; the same tooth of *longirostris* has a poorly developed and faintly pigmented third accessory tine (Richards, in prep.). *Myotis* species clusters were identified by comparing dentary alveolar lengths with dentary occlusal lengths of the various *Myotis* species as given by Miller and Allen (1928); this followed the method of Guilday, *et al.* (1977). Dentaries segregated into several size groups, suggesting the presence of *Myotis leibii* (mode, 5.2), *M. lucifugus*, *M. sodalis*, and/or *M. austroriparius* (mode, 5.6), and *M. keeni* or *M. grisescens* (6.1-6.6 size range) (Figure 4). *Plecotus* dentaries were identified by the single-rooted p4 (Guilday, 1961), and by characters of the m1-m2 (Handley, 1956). *Peromyscus* cf. *P. leucopus* was identified by the bilaterally symmetrical anteroconid of relatively unworn m1's (as viewed from above); the buccal portion of that tooth is less well developed in *P. maniculatus*, skewing the anteroconid lingually (Guilday, and Handley, 1971; Ray, 1967). Absolute size did not segregate the two morphologies, as *Peromyscus* cf. *P. maniculatus* included the largest and smallest specimens. *Microtus ochrogaster* possesses an m1 with an open "C" shape in the 3rd buccal reentrant angle (BRA 3, terminology of Martin, 1987), and triangle 6 projects laterally, and sometimes anteriorly. *Microtus pinetorum*, with dentition almost indistinguishable from that of *M. ochrogaster*, possesses an m1 with a relatively narrow, posteriorily directed BRA 3, and a relatively posteriorly directed triangle 6 (pers. comm., Martin to Richards, October 1988). *Microtus pennsylvanicus* can be separated from the dentally similar *M. chrotorrhinus* by its distinctive M2 and M3 (Semken, 1984).

PUBLISHED RECORDS: The *Bootherium* remains were incorrectly identified as those of *Camelops* sp., based upon comparisons with the selenodont third lower molar (Richards, 1984). Other taxa in the deposit (*Phenacomys*, *Clethrionomys*, and *Martes*) were described in previous papers (Richards, 1986, 1989) and the muskox association noted.

COMMENTS: The King Leo Pit Cave fauna suggests an environmental mosaic during its deposition. The tree squirrels (including *Glaucomys*) indicate the presence of deciduous (*Sciurus* sp.) as well as coniferous (*Tamiasciurus hudsonicus*) forests (Burt, and Grossenheider, 1964). The presence of *Martes pennanti*, *Clethrionomys gapperi*, and *Phenacomys intermedius* indicate coniferous, or mixed forests, the latter more indicative of dry, open conifer environments (Burt, and Grossenheider, 1964). All three of these taxa presently occur to the north of Indiana, and *Tamiasciurus* does not occur in the southern part of the state where the cave is located (Mumford, and Whitaker, 1982). The *Sorex hoyi* dentary has the large size (total mandibular length including incisor: 8.50 mm) of more northern subspecies (*S. h. hoyi* or *S. h. thompsoni*), contrasting with the small size of modern Indiana specimens (*S. h. winnemana*) (Richards, unpubl. data). A number of other taxa (*Cryptotis parva*, *Microtus pennsylvanicus*, *M. ochrogaster*, and *Peromyscus* cf. *P. maniculatus*) suggest more open vegetation (Burt, and Grossenheider, 1964). The dominance of *Peromyscus* cf. *P. maniculatus*, an inhabitant of relatively dry, open fields, over *P.* cf. *P. leucopus*, primarily a woodland species, is interesting, as *P. leucopus* and *Phenacomys intermedius*, are allopatrically distributed today, and would not be expected to occur together (Hall, 1981). This suggests that open, boreal environments were more prevalent during deposition than forested, temperate environments (of *P. leucopus*). The overall fauna suggests an environmental mosaic of open coniferous forest interspersed with open areas during deposition. There were apparently some broadleafed tree species present. This interpretation of an environmental mosaic is consistent with interpretations of other late Pleistocene faunas in the Midwest (Graham, 1976, 1985; Graham, and Mead, 1987; Lundelius, *et al.*, 1983).

Plecotus is presently rare in Indiana. It usually roosts in the cooler drafty entrance areas of caves (Mumford, and Whitaker, 1982), suggesting the presence of a previous entrance near the fossil deposit. *Myotis leibii*, suggested by the short dentary alveolar lengths (mode, 5.2), has not been recorded previously in Indiana. Several of the bats displayed alveolar pathologies. Many of the small bones, including those of bats and mice, were splintered and crusted with a white, chalky mass. These conditions suggest that the broken, crusted bones were part of the scat of a carnivore, perhaps of *Martes pennanti*.

Contemporaneity between *Bootherium* and the microfauna appears well demonstrated as the muskox occurred both on the surface and buried in the upper levels of the less than 20 cm deep deposit that appeared relatively homogenous in texture. Some of the microfauna, however, could have been deposited before or after entry of the muskox bones. The *Bootherium* remains were originally preserved in polyurethane (driven with mineral spirits), although some were later further consolidated with glyptal. The fauna is reposited at the Indiana State Museum, under catalogue numbers 71.3.74 (*Bootherium*), 71.3.75 (*Martes*), and 71.3.76 (remaining fauna).

DISCUSSION

Including the new finds, there is a notable bias of male to female *Bootherium* crania (ca. 18-2) in Indiana. McDonald and Ray (1989a) note that there is a general

disparity of female crania to those of males in North America. A female:male ratio of .29 was found among the sample they studied. They attribute the lack of female fossils to the smaller, lighter female skull that is more susceptible to destruction by weathering, abrasion, carnivore action, etc. than male crania, and cite the female:male ratio of .08 (three females: thirty-eight males) for recovered cranial fossils of the extant muskox, *Ovibos moschatus*. That differential preservation may be a factor in the ratio disparity is indicated by the many muskox crania that display extensive weathering, abrasion, and fragmentation. The Madison County cranium had disintegrated to the point where it could easily have been mistaken as a tree stump among the wood and roots of the surrounding peat deposit. Two additional females are suggested by the small size of the Madison County vertebra, and of some King Leo Pit cave postcranial elements.

It is interesting, however, that both of the female crania were recovered from sand and gravel deposits along major glacial sluiceways in southern Indiana, yet have not yet been identified from peat deposits of northern and central Indiana where male crania are most numerous.

The Clarksville and the King Leo Pit Cave *Bootherium* remains are the only two records of muskox from south-central Indiana, and the latter includes the only suite of associated postcranial remains of *Bootherium* reported from the state. Deposition in the cave has favored the recovery of associated microfauna. The associated taxa suggest that the environment at the time of deposition was one of predominantly coniferous forest interspersed with open areas, an environment consistent with other interpretations of *Bootherium* paleohabitat.

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