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MAMMALS FROM THE BLUE ASH LOCAL FAUNA (LATE OLIGOCENE), SOUTH DAKOTA. RODENTIA, PART 2: FAMILIES FLORENTIAMYIDAE AND GEOMYIDAE

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ABSTRACT

Three species of florentiamyid, *Florentiamys* sp. cf. *F. kingi* Wahlert, *Kirkomys parvus* (Troxell), and *Hitonkala martintau* n. sp., and an undetermined species of geomyid are recognized from the Blue Ash fauna. This increases the total number of rodents described from this fauna to 14. *Florentiamys* sp. cf. *F. kingi* is similar in morphology to the Arikareean *F. kingi*, but is slightly smaller. This is the first record of *Kirkomys parvus* other than the holotype, which is known from an uncertain horizon. *Hitonkala martintau* is distinct from the previously known Arikareean species of the genus by its more primitive cheek tooth morphology (smaller stylar cusps on upper molars; less molariform premolars). Specimens of the undetermined geomyid cannot be assigned to any currently known species of geomyoid from either the Arikareean or earlier. The smaller size of *Florentiamys* sp. cf. *F. kingi* and more primitive dental morphology of *Hitonkala martintau* compared to similar Arikareean species suggest that the fauna is of very earliest Arikareean age or perhaps latest Whitneyan.

INTRODUCTION

Previously, ten species of rodents have been described in detail from the latest Whitneyan or earliest Arikareean Blue Ash local fauna (Emry and Korth, 2007; Korth, 2007a, 2007b). The only geomyoids previously described were the eomyids and heliscomyids (Korth, 2007b). The remainder of the geomyoids belong to the Florentiamyidae and Geomyidae. Based on previous identifications of rodents from the Blue Ash fauna, it was not possible to determine with certainty whether the fauna was Whitneyan or Arikareean in age. Both florentiamyids and geomyids are extremely diverse in the Arikareean (notably the Entoptychinae, which are limited to the Arikareean) and rare or absent in the Whitneyan and earlier horizons. This disparity in the fossil record of geomyoids may allow for a better assessment of the provincial age of the Blue Ash local fauna.

Dental nomenclature used below follows that of Korth (1997:fig. 1) and Korth and Branciforte (2007:fig. 1). Upper cheek teeth are represented by capital letters and lowers as lower case letters. Abbreviations for institutions: CM, Carnegie Museum of Natural History; MCZ, Museum of Comparative Zoology, Harvard; YPM, Yale-Peabody Museum.

SYSTEMATIC PALEONTOLOGY

Order Rodentia Bowdich, 1821
Family Florentiamyidae Wood, 1936
Florentiamys Wood, 1936
Florentiamys sp. cf. *F. kingi* Wahlert, 1983
(Figure 1, Table 1)

Referred Specimens—CM 76454, right p4; CM 76455, right dp4; CM 76456, left m1 or m2; CM 76457, right m3; CM 76458 and 76459, left dP4s; CM 76462, 76466, 76467, 76600, M1s; CM 76461, left M2; CM 76463, 76464, 76465, M3s.

Description—The lower premolar, CM 76454, is slightly longer than wide (Table 1) and narrower anteriorly than posteriorly (Figure 1A). A deep transverse valley separates the metalophid from the hypolophid. The metaconid is the largest cusp on the tooth and is round in occlusal outline. A narrow valley separates it from the protostylid. The protostylid consists of two distinct cuspules aligned posteriorly along the buccal side of the tooth. The posterior cuspule is the largest. The cuspules are fused, their apices only separated by a minute valley. The cusps of the hypolophid are joined along the center-line of the tooth and teardrop shaped. The bases of the cusps are fused. There is no indication of a hypostylid or hypoconulid.

Table 1. Dental measurements of *Florentiamys* sp. cf. *F. kingi* from Blue Ash local fauna. Abbreviations: L, anteroposterior length; W, transverse width. Measurements in mm.

CM#	dp4		p4		m1		m3	
	L	W	L	W	L	W	L	W
76455	1.65	1.47						
76454			2.15	1.90				
76456					1.88	2.12		
76457							1.60	1.83

	dP4		M1		M2		M3	
	L	W	L	W	L	W	L	W
76458	1.94	1.95						
76459	1.88	1.85						
76462			1.93	--				
76600					1.65	2.20		
76461					1.70	2.26		
76463							1.73	2.15
76464							1.74	2.16
76465							1.85	--

The deciduous lower premolar, CM 76455, is smaller than p4 with a more complex occlusal pattern. Along the anterior margin of the tooth are two fused anterostylids. A deep valley separates them from the metalophid. The metalophid consists of an equal-sized metaconid and protostylid, both positioned at their respective margins of the tooth and are connected by a low loph that crosses the center of the tooth. The hypolophid cusps are the same shape as in p4, but slightly more separated. They are closer to one another than the metalophid cusps. Buccal and slightly anterior to the hypoconid, along the buccal border of the tooth is a minute hypostylid. Along the posterior border of the tooth, at its center is a distinct hypoconulid that is only slightly smaller than the hypolophid cusps.

The single m1 or m2, CM 76456 (Figure 1B), is similar in occlusal pattern to that of other species of *Florentiamys* (see Wood, 1936a; Wahlert, 1983). The only variation that Wahlert (1983) saw in the different species of *Florentiamys* was the presence or absence of an anterior cingulum. This feature on the Blue Ash specimen is very short, originating from the protostylid and extending lingually to a point anterior to the apex of the protoconid. A very faint ridge is also present anterior to the metaconid. The anterior cingulum is clearly not continuous for the width of the tooth as in *Florentiamys loomisi*, and will likely be eliminated after only a little more wear on the tooth.

The m3, CM 76457, is also similar to that of other species (Figure 1C). It is smaller than m1 and the hypostylid is lacking, making the tooth narrower posteriorly than anteriorly.

The two specimens of dP4 (CM 76458, CM 76459) are assigned to this species based on size and relative complexity. The relative complexity of the occlusal surface of dP4 is similar to the larger and more complex (molariform) premolars of the larger florentiamyids (Figure 1D). DP4 is triangular in occlusal outline, the anterobuccal corner being extended anteriorly. Three major cusps, metacone, hypocone, and protocone, are of equal size and circular in occlusal shape. The former two are along the posterior edge of the tooth and form the metaloph. The hypocone is near the center of the posterior margin of the tooth. The two metaloph cusps are separated and united only by a posterior cingulum that attaches them posteriorly. Lingual to the hypocone is a small hypostyle along the lingual border. Anterior to it is a larger entostyle. These two stylar cusps are joined by a lingual cingulum that ends just anterior to the entostyle. After a shallow valley, the anterior cingulum begins again anterior to the protocone and is continuous around the anterobuccal corner of the tooth, and it continues along the buccal edge of the tooth, ending at a large mesostyle. A distinct paracone is present anterior to the mesostyle in the anterobuccal corner of the tooth. The mesostyle and paracone are of equal size.

On M1s from Blue Ash, the protocone is large, circular, and isolated from the anterior and lingual cingula (Figure 1E). The anterior cingulum runs from the paracone to the lingual margin of the tooth and is closely pressed to the metaloph cusps. On worn specimens there is no evidence of the cingulum. In all other features, M1 and M2 do not differ from those of other florentiamyids (see Wood, 1936a; Wahlert, 1983).

M3 is smaller than the first two molars and oval in shape (Figure 1F). The paracone and protocone are similar in morphology to the other molars, but the metaloph is greatly reduced. The metaloph cusps are reduced swellings along the posterior cingulum. There are no stylar cusps.

Discussion—The specimens from Blue Ash assigned to *Florentiamys* are closer to the type species, *F. loomisi* in size, but have the dental morphology of the larger *F. kingi* (Wahlert, 1983:tables 2, 3). The Blue Ash specimen of p4, CM 76454, also lacks the mesostylid and fused metaconid and protoconid seen on the p4 of *F. loomisi* (Wahlert, 1983:fig. 1). The p4 of *F. kingi* lacks this mesoconid and has an isolated metaconid as in the Blue Ash specimen of p4. The only difference between the premolar of *F. kingi* and the Blue Ash specimen is the lack of a hypostylid on the latter and its slightly smaller size (Table 1). The molars assigned to *Florentiamys* sp. cf. *F. kingi* differ from *F. kingi* only in size. The lower molar from Blue Ash (CM 76456) lacks a continuous anterior cingulum, as do molars of *F. kingi*. Specimens of *F. loomisi* have an anterior cingulum on the lower molars that extends the entire width of the tooth. Similarly, the upper molars from Blue Ash have an anterior cingulum that is positioned more closely to the protoloph, as in *F. kingi*, and are distinct from upper molars of *F. loomisi* that

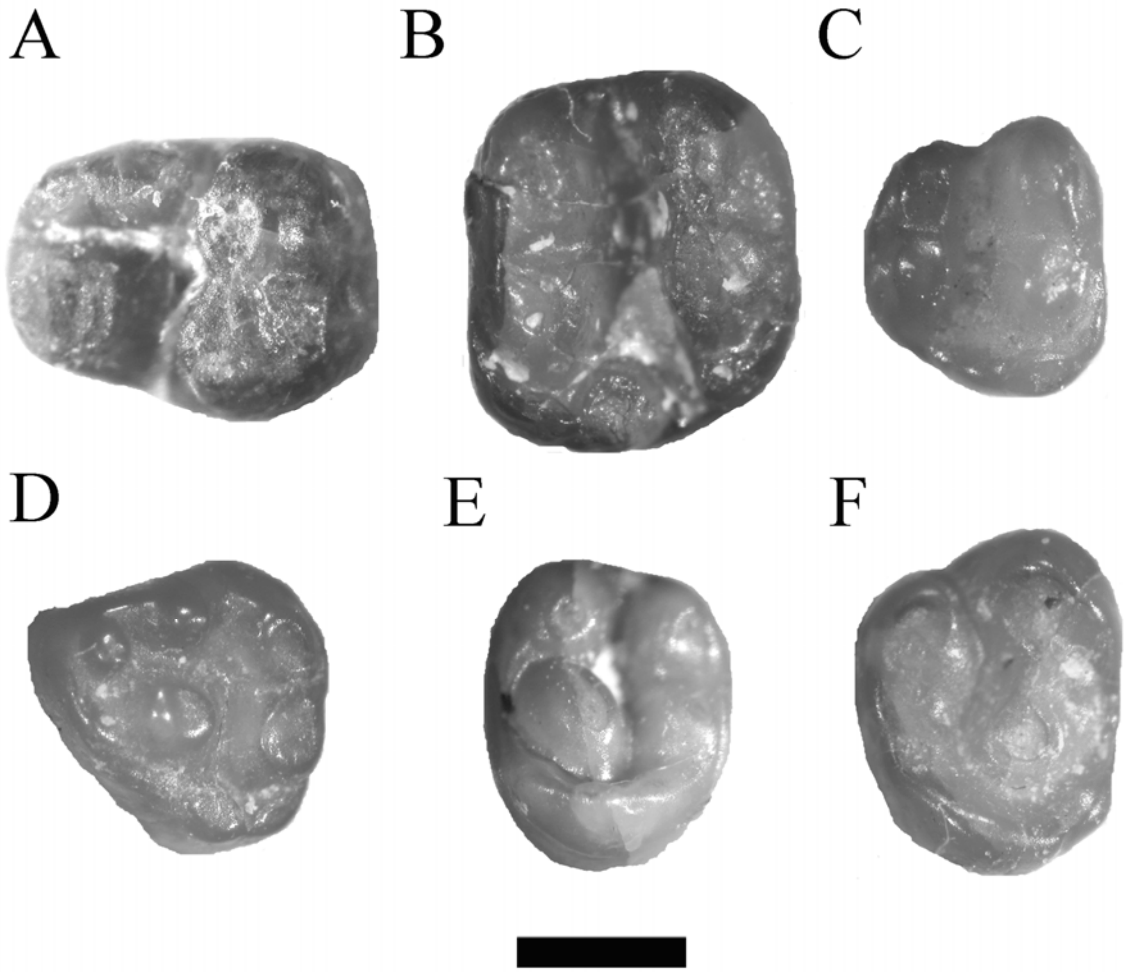

FIGURE 1. Cheek teeth of *Florentiamys* sp. cf. *F. kingi* from the Blue Ash local fauna. A, CM 76454, right p4. B, CM 76456, left m1 or m2. C, CM 76457, right m3. D, CM 76459. left dP4. E, CM 76600, left M1 or M2. F, CM 76464, right M3. Anterior to the left for A, B, D, and E; anterior to the right for C and F. Bar scale = 1 mm.

have an anterior cingulum that forms a wider shelf and even alters the occlusal shape of M3 to nearly circular rather than oval (Wahlert, 1983).

Kirkomys Wahlert, 1984
Kirkomys parvus (Troxell, 1923)
(Figure 2A-H, Table 2)

Referred Specimens—CM 76468 – 76473, partial maxillae with P4-M1; CM 76475, partial maxilla with P4; CM 76476, partial maxilla with P4-M2; CM 76479, partial maxilla with M2-M3; CM 76482, 76489, 76500, 76572, 76573, P4s; CM 76494, dP4; CM 76483, 76486, 76488, 76490, 76491, 76496, 76499, 76540, 76544, 76545, 76551, 76553, 76554, 76558, 76566, 76570, 76606, M1s; CM 76477, 76480, 76481, 76487, 76492, 76493, 76498, 76534, 76542, 76547, 76548, 76555, 76560, 76561, 76565, 76568, M2s; CM 76502, dP4. CM 76508, mandible with m1-m3; CM 76503 – 76507, 76511, 76512, 76535, 76607, p4s; CM 76513, 76515, 76520 – 76523, 76527 – 76529, 76531 – 76533, 76579, 76582, 76590 – 76592, 76596, 76598, m1s; CM 76509, 76514, 76516 – m76518, 76524, 76525, 76530, 76588, 76597, 76601, m2s; CM 76584, 76586, m3s.

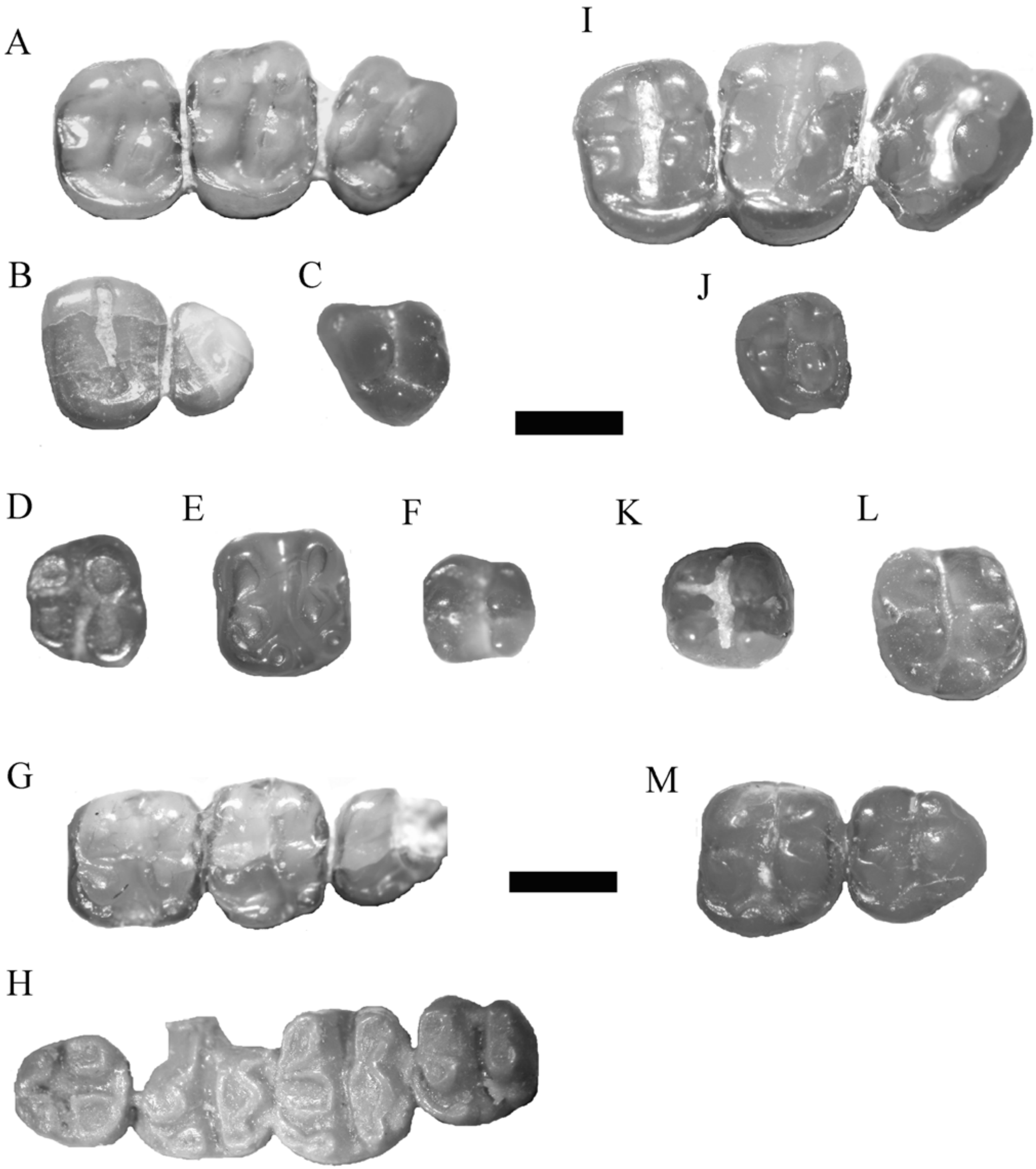

FIGURE 2. Dentitions of *Kirkomys parvus* and *Hitonkala martintau* from the Blue Ash local fauna. A-H, *K. parvus.* A, CM 76476, right P4-M3. B, CM 76479, left M2-M3. C, CM 76494, left dP4. D, CM 76564, right p4. E, CM 76522, left m1. F, CM 76584, right m3. G, CM 76508, left m1-m3 (partial); H, YPM 10362 right p4-m3 – reversed (holotype), . I-M, *H. martintau*. I. CM 76563, right P4-M3. J, CM 76543, right M3. K, CM 76574, right p4 (holotype). L, CM 76585, right m1. M, CM 76578, left m2-m3. Bar scale = 1 mm. Anterior to the right on A, I, J, and L; to the left on all other figures.

Amended Diagnosis—Similar in size to *K. nebraskensis*, larger than *K. schlaikjeri*; p4 longer than wide (p4 of *K. nebraskensis* equal in length and width or slightly shorter than wide); lower premolar lower-crowned than in *K. nebraskensis* (crown height index for *K. parvus* = 0.46; for *K. nebraskensis* = 0.63); posterior cingulum present on P4 and M1 (absent on *K. nebraskensis*); M1 slightly larger than M2 (M1 and M2 equal in size in *K. schlaikjeri*).

Description—The upper premolar is smaller than the first molar and similar to other geomyoids in morphology (Figure 2A). The protoloph consists of a single, oval protocone that is transversely elongated. On only four of the 14 specimens of P4, there is a paracone present that is much smaller than the protocone and the metaloph cusps. The metaloph consists of three cusps, the central hypocone is the largest and circular in occlusal outline. The metacone is slightly smaller than the hypocone and positioned just anterior to it, along the posterobuccal corner of the tooth. Along the posterior border of the tooth on the buccal side, posterior to the metacone and buccal side of hypocone is a small posterior cingulum. This cingulum is not variable, and is present on all specimens. The entostyle is subequal in size to the metacone, but is transversely compressed (anteroposteriorly elongated). It is separated from the hypocone by a narrow valley that is variable in width among the specimens present. The protocone is separated from the metaloph cusps by a deep transverse valley.

DP4 is slightly smaller than P4, but is expanded in the anterobuccal corner (Figure 2C). The enamel appears to be much thinner than on the P4s of the sample. In general morphology it is similar to P4, but a small paracone is present buccal to the protocone and it extends much farther anteriorly.

M1 is the largest of the upper cheek teeth. It is much wider than long. The protoloph consists of two major cusps, paracone and protocone. The protocone is slightly larger than the paracone. The anterior cingulum originates anterior to the paracone and continues along the anterior edge of the tooth, then curves posteriorly to form the lingual cingulum. The protocone is separated from the lingual cingulum by a deep narrow valley. The stylar cusps are not distinct on the lingual cingulum, but appear as two small swellings lingual to the protocone and hypocone respectively. The transverse valley that separates the two lophs of the tooth is interrupted lingually by the lingual cingulum. The lingual cingulum ends posteriorly at the hypcone. Posterior to the metacone on specimens with little wear is a distinct, but thin posterior cingulum that originates at the posterobuccal side of the hypocone and continues buccally to the edge of the tooth. This cingulum disappears in early wear.

M2 is similar to M1, but is slightly smaller. It differs from M1 in that there are no discernable stylar cusps on the lingual cingulum and there is a posterior cingulum on M2, only on unworn specimens.

Only one specimen, CM 76479, preserves M3, and it is heavily worn (Figure 2B). The tooth is much smaller than either M1 or M2, and roughly triangular in occlusal outline. The only identifiable cusps are those of the protoloph, the metaloph and posterior half of the tooth being greatly reduced.

The morphology of the lower premolar is surprisingly consistent in the sample (Figure 2D), and similar to that of the holotype of *Kirkomys parvus* (Korth, 2008:fig. 1B; Figure 2H, this paper). The metalophid cusps are smaller than the hypolophid cusps, making the tooth narrower anteriorly than posteriorly. The tooth is always longer than wide. The metalophid cusps are joined anteriorly and nearly equal in size, the protostylid being slightly smaller on a few specimens. The anterior connection of these cusps (anterior cingulum) is interrupted by a minute valley on only two of the nine specimens. There is always a minute hypoconulid along the posterior border of the tooth at its center, aligned with the narrow valley that separates the hypolophid cusps. A hypostylid is never present. The crown-height index (buccal crown height divided by maximum width: see Korth and Branciforte, 2007: fig. 1) for p4 averages 0.44, slightly lower than in the holotype 0.46 (Table 2).

The first lower molar is nearly square in occlusal outline; nearly as long as wide (Figure 2E, G). The four major cusps, metaconid, protoconid, hypoconid, and entoconid are nearly equal in size. A deep transverse valley separates the hypolophid from the metalophid. A thin anterior cingulum runs the entire width of the tooth along the anterior border, fusing centrally with the anterior margin of the protocone. The protoconid and metaconid fuse along the anterior cingulum via low projections that run anterobuccally from the metaconid and anterolingually from the protoconid. The anterior cingulum is continuous around the anterobuccal corner of the tooth, curving posteriorly and ending at a small protostylid, near the center of the buccal margin of the tooth. Posterior to it, buccal to the hypoconid, is a small, isolated hypostylid. A distinct posterior cingulum is present running from the posterior base of the hypoconid to the lingual edge of the tooth, posterior to the entoconid. The average crown height index for m1 is 0.33 (range = 0.21-0.41), very near that of the holotype (0.35).

The second lower molar is distinct from m1 in shape, being as wide as the anterior molar, but much shorter (Figure 2G). Other than proportions, the only difference in the occlusal morphology of m2 from m1 is that the anterior cingulum does not extend lingually from the protoconid.

The m3 is the smallest molar (Figure 2F, G). The metalophid cusps are similar in arrangement and proportion to those of m2, but the protostylid and lingual cingulum are more reduced. The hypolophid is greatly reduced. The major cusps are smaller than the metalophid cusps, making the tooth narrower posteriorly. A hypostylid is absent on two of the specimens, and only a minute cuspule occurs on the other (CM 76586).

TABLE 2. Dental measurements of *Kirkomys parvus* from the Blue Ash local fauna. Additional abbreviations: N, number of specimens; M, mean; OR, range of measurements; SD, standard deviation; CV, coefficient of variation; ht, crown height (measured buccally); ht/W ratio of crown height to width. Measurements in mm. Measurement for holotype, YPM 10362, from Korth (2008:table 1)

		N	M	OR	SD	CV	TYPE
p4	L	9	1.13	1.06-1.21	0.04	3.52	1.12
	W	9	1.03	0.94-1.09	0.05	4.66	1.03
	ht	9	0.46	0.38-0.57	0.06	12.59	
	ht/W	9	0.44	0.39-0.55	0.05	11.55	0.46
m1	L	19	1.24	1.14-1.34	0.05	4.13	1.25
	W	20	1.30	1.20-1.37	0.05	3.51	1.27
	ht	17	0.44	0.28-0.56	0.06	14.76	
	ht/W	17	0.33	0.21-0.41	0.05	14.38	0.35
m2	L	12	1.10	1.03-1.21	0.05	4.55	1.26
	W	12	1.30	1.19-1.37	0.06	4.26	1.43
m3	L	3	1.02	0.90-1.19	0.15	14.64	1.07
	W	3	1.03	0.99-1.07	0.04	3.94	1.12
P4	L	14	1.28	1.09-1.44	0.10	7.77	
	W	13	1.36	1.30-1.47	0.06	4.08	
M1	L	25	1.16	1.07-1.29	0.07	5.61	
	W	25	1.48	1.39-1.55	0.04	2.93	
M2	L	18	1.08	0.97-1.15	0.05	4.61	
	W	18	1.41	1.31-1.54	0.06	4.35	
M3	L	1	0.76				
	W	1	1.01				

Discussion—The lower cheek teeth referred here to *Kirkomys parvus* are identical with those of the holotype, YPM 10362, in occlusal morphology and crown-height (Korth, 2008). The upper cheek teeth have been referred to this species based on compatible size and morphology. Korth (2008) noted that the proportions and crown-height of p4 separated *K. parvus* from the holotype and referred specimens of *K. nebraskensis*; the latter having p4 wider than long and being slightly higher crowned. The upper cheek teeth differ from those of *K. nebraskensis* (see Korth and Branciforte, 2007) in the presence of a posterior cingulum on both P4 and M1.

Although the exact horizon of the holotype of *Kirkomys parvus* is unknown, Korth (2008) suggested that it likely came from the Whitneyan of Colorado. The presence of this species in the Blue Ash fauna (latest Whitneyan or earliest Arikareean) supports this age interpretation.

Kirkomys parvus is the most abundant species of geomyoid from the Blue Ash fauna. It can be separated from specimens of *Hitonkala* from this fauna by its slightly smaller size and higher crown-height of the cheek teeth, along with a few morphological differences (see below discussion).

In Wahlert's (1984) original description and diagnosis of *Kirkomys*, he included *Heliscomys schlaikjeri* Black, 1961, from the Arikareean of Wyoming as a referred species of the genus. Wahlert cited three dental morphologies that separated it from the type species *K. nebraskensis* (=*K. milleri*, see Korth and Branciforte, 2007): 1) presence of a posterior cingulum on P4 of *K. schlaikjeri*; 2) amount of separation of the protocone from the lingual cingulum (narrow valley in *K. schlaikjeri*); and 3) width of the anterior cingulum on the upper molars (wider in *K. schlaikjeri*). Of these features, based on the sample of *K. parvus* from Blue Ash and the large sample of *K. nebraskensis* from the early Arikareean of Nebraska (Korth and Branciforte, 2007), the second and third morphologies appear to be quite variable within both of these populations, and therefore are not significant specific characters. However, the presence of a posterior cingulum on P4 is consistent in both samples; present on all of the premolars from Blue Ash, and absent from all of the referred premolars of *K. nebraskensis*.

A final character used by Wahlert (1984) to separate *K. nebraskensis* (=*K. milleri*) from *K. schlaikjeri* was the curvature of the posterior edge of the maxilla onto the base of the zygoma. In *K. nebraskensis* the maximum curvature was anterior to P4, and in *K. schlaikjeri* it was lateral to P4. Ony three specimens of *K. parvus* from Blue Ash retain the base of the zygoma. All of these have the maximum curvature lateral to P4 as in *K. schlaikjeri*.

Korth and Branciforte (2007) suggested that *H. schlaikjeri* (known only from a single specimen, MCZ 7335) was more likely referred to a new genus *Proharrymys* based on the presence of this posterior cingulum on P4. However, *H. schlaikjeri* differed from the type species of *Proharrymys* in lacking a relatively large paracone on P4. It now appears likely that Wahlert's (1984) reference of *H. schlaikjeri* to *Kirkomys* may be correct because of the occurrence of this feature on *K. parvus*. *K. schlaikjeri* differs from *K. parvus* in being slightly smaller and having M1 and M2 of equal size (see Wahlert, 1984:table 1; Table 2 this paper), whereas, M1 is generally larger than M2 in *K. parvus* (Table 2).

Hitonkala Macdonald, 1963
Hitonkala martintau n. sp.
(Figure 2I - M, Table 3)

Type Specimen—CM 76574, right p4 (Figure 2K).

Referred Specimens—CM 76474, partial maxilla with M1-M2; CM 76536, maxilla with P4-M2; CM 76478, 76484, 76495, 76497, 76537 – 76539, 76541, 76546, 76549, 76559, 76562, 76563, 76567, 76571, 76604, 76605, M1s; CM 76550, 76552, 76556, 76557, 76564, 76569, M2s; CM 76485, 76543, M3s. CM 76578, partial mandible with m2-m3; CM 76575 – 76577, p4s; CM 76510, 76581, 76585, 76594, 76595, m1s; CM 76526, 76580, 76583, 76587, 76589, 76593, 76599, 76602, m2s; CM 76519, 76603, m3s.

Diagnosis—Slightly smaller size than other species; posterior cingulum on P4 (absent in other species); lingual stylar cusps on M1 smaller than in other species (lingual cingulum not divided); p4 longer than wide (as in *H. macdonaldtau*); protoconid on p4 anterior to other metalophid cusps and anteroposteriorly elongated; hypostylid minute or absent and anterostylid absent on p4 (both present on p4 of other species).

Etymology—Patronym for James E. Martin of the Museum of Geology, South Dakota School of Mines and Technology; and *-tau*, genitive singular suffix in Sioux.

Description—Only a single specimen contains a P4, CM 76536 (Figure 2I). It is nearly equal in width to M1 (Table 3). The metaloph consists of three cusps, the buccal metacone, central hypocone, and lingual hypostyle. The hypostyle is transversely compressed. Posterior to the metacone and hypocone is a short posterior cingulum. The protoloph consists of a central protocone, the largest cusp on the tooth, and a paracone that is on the anterobuccal slope of the protocone and only slightly smaller than the metacone.

M1 is wider than long, and dominated by the four major cusps, the paracone and protocone of the protoloph, and the metacone and hypocone of the metaloph. All of these cusps are round in occlusal outline and nearly equal in size. A deep central transverse valley separates the lophs. An anterior cingulum arises from the lingual side of the paracone, extends to the lingual margin of the tooth, wraps around the anterolingual corner, and is continuous with the lingual cingulum. The protocone is joined to the paracone, but is isolated from the anterior and lingual cingula except in specimens with extreme wear. There are two distinct stylar cusps on the lingual cingulum, the protostyle in the anterolingual corner of the tooth, and the hypostyle that is just posterior to the center of the lingual margin of the tooth, blocking the transverse valley. There is a small notch in the lingual cingulum between the stylar cusps. There is no indication of a posterior cingulum on any of the specimens. A small mesostyle is attached to the posterobuccal corner of the paracone on only one specimen, CM 76559, and absent on all others.

M2 is distinguished from M1 in that it is much shorter, but it is nearly as wide (Table 3). M2 differs from M1 in having smaller stylar cusps that have been reduced to small swellings on the lingual cingulum, and there is no break in the lingual cingulum between the stylar cusps.

M3 is smaller than M1 and M2 and oval in occlusal outline (Figure 2J). The major cusps are smaller than the other molars and the anterior cingulum originates nearly at the anterobuccal corner of the tooth and is continuous with the lingual cingulum, ending posteriorly at the posterior margin of the hypocone. There are no stylar cusps present, and no break in the lingual cingulum.

The lower premolar is similar in size to that of *Kirkomys parvus*, but is slightly lower-crowned (Table 2 and 3). The metalophid consists of three distinct cusps (Figure 2K). The central protoconid is the smallest and is laterally compressed. The presence of the third cusp makes the metalophid nearly equal in width to the hypolophid. The protostylid is slightly smaller than the metaconid. The hypoconid consists of two equal-sized cusps, the hypoconid and entoconid. The central transverse valley separates the two lophs. At the center of the posterior margin of the tooth is a small hypoconulid. On two specimens, CM 76574, and CM 76575, there is a minute hypostylid lateral to the hypoconid.

The first lower molar is slightly wider than long and lower-crowned than specimens of *Kirkomys parvus* (Table 2 and 3). The occlusal pattern of the molars is similar to that of the latter and other geomyoids, being composed of two transverse lophs of two cusps each with a smaller stylar cusp at the buccal end of the loph (Figure 2L). The anterior cingulum extends the entire width of the tooth, fusing with the anterior margin of the protoconid at the center. The anterior cingulum ends buccally, it is separated from the protostylid by a narrow valley. The hypostylid is even with the major cusps of the hypolophid but smaller and posterior to the protostylid. The posterior cingulum is variable. On all specimens it is a cuspule along the posterior margin of the tooth, even with the valley between the hypconid and entoconid. In some specimens, a short narrow ridge runs lingually from the cuspule, posterior to the entoconid.

The second lower molar is similar in occlusal morphology to m1, is nearly as wide, but is shorter anteroposteriorly. The only differences in morphology are that the anterior cingulum is reduced (shorter, more closely appressed to the lophids). The posterior cingulum is a thin lophid that extends the entire width of the tooth.

The last lower molar is posteriorly reduced. The length of the tooth is nearly equal to that of m2, but the hypolophid cusps are reduced in size, making the tooth much narrower posteriorly (Figure 2M). The metalophid is similar in morphology to that of m2 but the anterior cingulum is lacking and the protostylid is much smaller. The hypostylid is reduced to a minute swelling at the base of the hypoconid. There is no posterior cingulum.

TABLE 3. Dental measurements of *Hitonkala martintau* from the Blue Ash local fauna. Abbreviations as in Tables 1 and 2. Measurements in mm.

		N	M	OR	SD	CV
P4	L	1	1.56			
	W	1	1.63			
M1	L	18	1.27	1.19-1.43	0.06	4.70
	W	17	1.63	1.51-1.78	0.09	5.50
M2	L	9	1.17	1.11-1.23	0.05	4.08
	W	9	1.58	1.53-1.64	0.04	2.58
M3	L	2	0.97	0.94-1.00		
	W	2	1.20	1.20-1.20		
p4	L	4	1.11	1.04-1.19	0.06	5.58
	W	4	1.03	0.95-1.12	0.08	7.80
	ht	4	0.39	0.33-0.47	0.06	15.05
	ht/W	4	0.38	0.35-0.42	0.03	7.96
m1	L	4	1.36	1.30-1.39	0.04	2.98
	W	5	1.45	1.38-1.50	0.05	3.35
	ht	5	0.37	0.32-0.45	0.05	13.09
	ht/W	5	0.26	0.21-0.30	0.03	12.82
m2	L	9	1.19	1.15-1.21	0.02	1.42
	W	9	1.45	1.37-1.56	0.07	4.81
m3	L	3	1.17	1.09-1.23	0.07	6.08
	W	3	1.22	1.17-1.28	0.06	4.56

Discussion—Specimens referred here to *Hitonkala martintau* are referred to this genus based on the diagnostic features of the presence of a protoconid on p4 and the distinct stylar cusps on M1 (Macdonald, 1963; Korth, 1992). *Hitonkala martintau* differs from the other described species of *Hitonkala* by the slightly smaller size of the stylar cusps on M1, presence of a posterior cingulum on P4, less molariform P4 than *H. madconaldtau* (no parastyle), and less molariform p4 than *H. andersontau* (no anterostylid and minute to absent hypostylid). All of the features that separate *H. martintau* from the other species of the genus appear to be primitive for the genus. Both of the other species of *Hitonkala* are Arikareean in age (Macdonald, 1963; Korth, 1992).

In the Blue Ash fauna, both *Kirkomys parvus* and *Hitonkala martintau* are represented almost entirely by isolated teeth. However, they can be separated from one another based on a number of morphologies. Although there is some overlap in size range, *H. martintau* specimens are generally larger and lower-crowned than those of *K. parvus* (Table 2 and 3). In the upper dentition, the premolar of *H. martintau* is nearly equal in width to M1, whereas in *K. parvus*, P4 is distinctly smaller. The paracone on P4 of *H. martintau* is larger relative to the protocone than in *K. parvus*, where the paracone is variable in occurrence and always smaller than in *H. martintau*. The upper molars of *H. martintau* lack the posterior cingulum that is present on specimens of *K. parvus*. The stylar cusps on M1 of *H. martintau* are much larger than those on M1 of *K. parvus* where they are small swellings along the cingulum that are only variably present.

The greatest difference between the cheek teeth of *K. parvus* and *H. martintau* is in the morphology of p4. Although the p4 of these species are nearly identical in occlusal dimensions, those of *H. martintau* are lower-crowned. The presence of a third cusp (protoconid) on the p4 of *H. martintau* makes the metalophid nearly as wide as the hypolophid. On specimens of *K. parvus* there is never a protoconid and the metalophid is always narrower than the protoconid. The variable hypostylid present on half of the specimens of *H. martintau* is never present on any specimen of *K. parvus*. The first lower molar of *K. parvus* is nearly equal in length and width, whereas those of *H. martintau* are slightly wider than long. The cingulum at the anterobuccal corner of m1 and some m2 of *H. martintau* ends anterior to the protostylid. On specimens of *K. parvus* the cingulum is continuous with the protostylid.

Family Geomyidae Bonaparte, 1845
Genus and species uncertain
(Figure 3)

Referred Specimens—CM 76451, left P4; CM 76452, right p4; and CM 76453 and CM 76460, M1 or M2.

Measurements—CM 76451, P4; L = 1.88 mm, W = 2.12 mm. CM 76452, p4; L = 1.96 mm, W = 1.66 mm, ht/W = 0.63. CM 76453, M1 or M2; L = 1.96 mm, W = 2.43 mm. CM 76460, M1 or M2; L = 2.04 mm; W = 2.58 mm.

Description—P4 (CM 76451) is simple in occlusal morphology (Figure 3A). There are four recognizable cusps; an isolated protocone in the protoloph, and a three-cusped metaloph with metacone, hypocone, and entostyle. The protocone is oval with the long axis oriented buccolingually, but no indication of any accessory paracone or stylar cusps. The metacone and hypocone are subequal in size and positioned closely together, the hypocone being at the center of the posterior margin of the tooth. The entostyle is transversely compressed and positioned more anteriorly than the other metaloph cusps at the lingual end of the central transverse valley. There is no indication of a posterior cingulum.

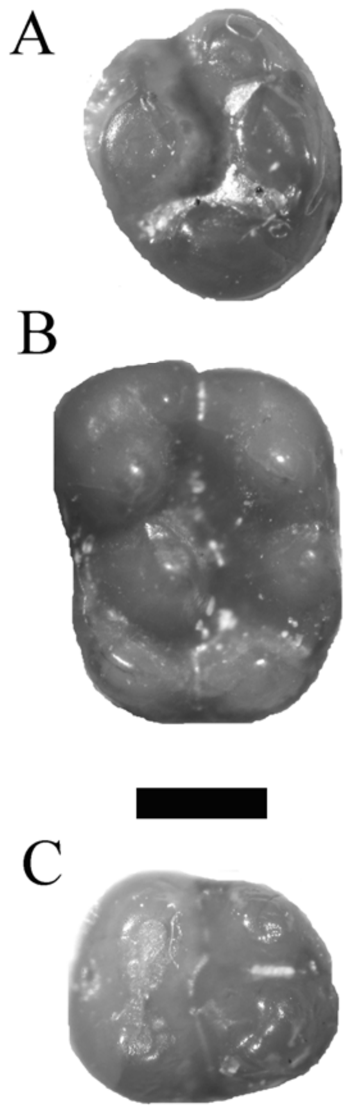

FIGURE 3. Cheek teeth of indeterminate geomyid from Blue Ash local fauna. A, CM 76451, right P4. B, CM 76453, left M1 or M2. C, CM 76452, right p4. Anterior to the left for A and B; anterior to the right for C. Bar scale = 1 mm.

The lower premolar (CM 76452) is also fairly simple in occlusal pattern. There are four distinct cusps (Figure 3C). The metalophid consists of a small, isolated metaconid and a slightly larger and more complex protostylid. The metaconid is the smallest cusp of the tooth and circular in occlusal outline, separated from the entoconid and protostylid by deep valleys. The protostylid has two short extensions running posteriorly from the apex. Along the buccal edge of the tooth a short, round loph extends slightly posterior to the apex of the cusp. On the lingual side of the cusp is a narrower, lower loph that slopes downward into the central basin of the cusp. The two hypolophid cusps are of equal size and slightly anteroposteriorly compressed. They join one another at the midline of the tooth, both forming teardrop-shaped wear facets. The valley that separates the hypolophid cusps from one another is much shallower than the central transverse valley. A minute hypoconulid is present along the posterior margin of the tooth at its center, aligned with the valley separating the hypoconid and entoconid.

The isolated upper molars are wider than long and have two rows of three cusps each (Figure 3B). The cusps are distinct and the tooth is only weakly lophate. The four major cusps (paracone, protocone, metacone, hypocone) are of equal size and round in occlusal outline. The stylar cusps are only slightly smaller in size and separated from one another by a deep notch on the lingual cingulum. The stylar cusps are closer together on CM 76460. The anterior cingulum runs from the base of the paracone anterior to the protocone, joining the protostyle lingually. The entostyle is continuous with the hypocone and there is no posterior cingulum. The tooth is slightly expanded buccal to the paracone, and a small stylar cusp (?mesostyle) is buccal to the paracone, just anterior to the central transverse valley of the tooth.

Discussion—The three teeth assigned here to “Geomyid genus and species uncertain” are considered to represent the same species because of their similar size, crown-height, and relatively simple (primitive) geomyoid morphology. The lack of any additional isolated cheek teeth of similar size and morphology belonging to any other species recognized in the fauna lend additional support to this assumption. However, it is possible that more than a single species is represented by these specimens.

These specimens cannot be assigned to any currently known entoptychine because of their lower crown-height, weak loph development and simplicity of the occlusal pattern of the premolars. In all entoptychines from the Arikareean (*Pleurolicus*, *Gregorymys*, and *Entoptychus*) the cheek teeth have very well developed transverse lophs, much higher crowned cheek teeth, and premolars with much more complex occlusal morphologies (see Wood, 1936b; Rensberger, 1971, 1973). Similarly, specimens of the heteromyid *Schizodontomys* are of similar size to the Blue Ash geomyoid with primitive premolar morphology, but the former has much higher-crowned, more lophate teeth (see Rensberger, 1973; Korth, 1997).

The specimens described above are similar in crown-height to the cheek teeth of florentiamyids, but again, the morphology of the premolars is far more complex in similarly sized florentiamyids (see Wahlert, 1983). Also, the stylar cusps of the upper molar are much larger, and the lingual cingulum is not continuous as it is in florentiamyids.

The only geomyoid of similar size with relatively simple premolar morphology is *Tenudomys* (see Rensberger, 1973; Korth, 1993; Korth and Branciforte, 2007). The biggest difference between the Blue Ash upper molar and specimens of *Tenudomys* is the development of the lingual stylar cusps. In all species of *Tenudomys* the lingual cingulum on the upper molars is contiuous and the stylar cusps are very small or absent. P4 in *Tenudomys* has a paracone that is more enlarged and transversely elongated than in the Blue Ash specimen. P4 in most species of *Tenudomys* is equal to or larger than M1, whereas the Blue Ash specimen of P4 is much smaller than the upper molars. The lower premolar of *Tenudomys* is defined as having simple metalophid cusps (Rensberger, 1973). The Blue Ash specimen has a more complex protostylid than any species of *Tenudomys*.

AGE OF THE BLUE ASH GEOMYOIDS

The ten previously described rodents from the Blue Ash local fauna were not sufficient to determine the age of the fauna because of the number of unique species and lack of index fossils that define the Whitneyan or Arikareean (Korth, 2007b). It is also difficult to define the Whitneyan North American Land Mammal Age based on rodents because no diverse rodent fauna from the Whitneyan has been fully described. Although Setoguchi (1978) referred a fauna of micromammals from Wyoming to the Whitneyan, it was later demonstrated to be Orellan (Korth, 1989a). Below, the families of geomyoids are discussed separately in terms of horizon of occurrence in order to better determine the age of the Blue Ash fauna.

Heliscomyidae—The Heliscomyidae have their greatest diversity during the Orellan with seven described species (Korth and Branciforte, 2007). No species of heliscomyids have been previously reported from the Whitneyan and three species are known from the Arikareean: *Heliscomys macdonaldi*, *Tilionomys voorhiesi*, and *T. woodi* (McGrew, 1941; Korth and Branciforte, 2007). Only a single species is known from the Hemingfordian and Barstovian (see Korth, 1994). Clearly the number of species of heliscomyids decreased dramatically from the Orellan into the later Tertiary. Two species of heliscomyids are known from the Blue Ash fauna, *Heliscomys medius* and *Heliscomys* sp. The latter is identical to specimens of *Tilionomys voorhiesi* from the early-early Arikareean (=Ar1 of Tedford t al., 2004) in morphology and size (see Korth, 2007b; Korth and Branciforte, 2007) and should be referred to that species. The reduced number of heliscomyids follows the pattern of reduced diversity after the Orellan. After the early-early Arikareean, only a single species of heliscomyid is present at any horizon. This implies that the Blue Ash fauna is either earliest Arikareean or possibly earlier, but clearly not as early as Orellan.

Florentiamyidae—The only florentiamyid from the Orellan is *Ecclesimus tenuiceps* (Galbreath, 1948; Korth, 1989b). The only previously reported florentiamyid from the Whitneyan was the type species of *Kirkomys*, *K. nebraskensis* (=*K. milleri*) (Wood, 1937; Wahlert, 1984), along with an undescribed species from the Whitneyan of South Dakota (Korth and Branciforte, 2007). It has also been suggested that the holotype of *K. parvus* (=*Dilolophus parvus*) was from the Whitneyan (Korth, 2008). A large sample of *K. nebraskensis* is known from the earliest Arikareean of Nebraska (Korth and Branciforte, 2007) as well as *K. schlaiikeri* from Wyoming (Black, 1961). The presence of *K. parvus* in the Blue Ash fauna suggests a Whitneyan or earliest Arikareean age for the fauna.

Hitonkala was previously known from two species, both Arikareean in age (Macdonald, 1963, 1970; Korth, 1992). The species of *Hitonkala* from Blue Ash is slightly more primitive morphologically than the other known species (see above discussion), suggesting a slightly older age of the fauna.

Elsewhere, the earliest occurrence of the large florentiamyid *Florentiamys* is in the Arikareean where it is known from several species (Wood, 1936a; Wahlert, 1984). The similarly sized *Sanctimus* is also quite diverse in the Arikareean, being represented by several species (Macdonald, 1970; Wahlert, 1984). The species of *Florentiamys* from Blue Ash is morphologically similar to *F. kingi* from the Arikareean, but is smaller in size. The low diversity of *Florentiamys* and lack of *Sanctimus*, along with the smaller size of the species of the former, suggests that the fauna may be older than the Arikareean occurrences of these genera elsewhere.

Geomyidae—The only probable geomyid from the Orellan is a primitive species of *Tenudomys* (Korth, 1989b). No geomyids have been described from the Whitneyan, but several species of *Tenudomys* are known from the Arikareean (Rensberger, 1973; Martin, 1974; Korth, 1993; Korth and Branciforte, 2007). Also, during the Arikareean the entoptychine geomyids are very diverse (see Wood, 1936b; Rensberger, 1971, 1973). The lack of any entoptychines from the Blue Ash fauna suggests that it predates their first occurrence elsewhere in the Arikareean. However, the Ridgeview fauna from Nebraska is distinctly earliest Arikareean in age and also lacks entoptychines (Bailey, 2004; Korth and Branciforte, 2007). Because the undetermined species of geomyid from the Blue Ash fauna is not referable to *Tenudomys*, or any known genus of entoptychine (*Entoptychus, Gregorymys, Pleurolicus*), its presence in the fauna cannot be used to correlate with any other Arikareean or Whitneyan faunas.

Heteromyidae—The earliest occurring heteromyids are *Proheteromys* and *Proharrymys* from the Arikareean. Several species of the former are known throughout the Arikareean of North America (Wood, 1935; Macdonald, 1963; Korth, 1997; Albright, 1996). *Proharrymys* is known only from the earliest Arikareean (Korth and Branciforte, 2007). The lack of these genera from in the Blue Ash fauna, again suggests that it predates their occurrence in the Arikareean.

CONCLUSIONS

In summary, the lack of entoptychine geomyids and heteromyids in the Blue Ash fauna is most likely due to its earlier age than the first occurrence of these families. The presence of two species of heliscomyids from Blue Ash is intermediate between their great diversity in the Orellan and their rarity in the Arikareean and later. The low diversity of the larger florentiamyids, *Florentimays* and *Sanctimus*, similarly suggests an earlier age than Arikareean where several species of each of these genera are known, and the species of *Florentiamys* from Blue Ash is smaller than the most similar species from the Arikareean. These occurrences indicate that the Blue Ash local fauna is likely older than most of the early Arikareean faunas from the Great Plains but does not verify whether it is slightly before or slightly after the Whitneyan-Arikareean boundary. Study of the lagomorphs and marsupials resulted in a similar conclusion (Korth, 2007c).

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