

# THE EARLY HEMINGFORDIAN (EARLY MIOCENE) POLLACK FARM LOCAL FAUNA: FIRST TERTIARY LAND MAMMALS DESCRIBED FROM DELAWARE<sup>1</sup>

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## ABSTRACT

Land mammal fossils were discovered in 1992 in the lower part of the Calvert Formation at the Pollack Farm Site, a temporary excavation for highway construction, between Smyrna and Dover, Delaware. During the short time the pit was open the collection grew to become the most diverse Tertiary land mammal fauna known in eastern North America north of Florida. The assemblage, termed the Pollack Farm Local Fauna, includes at least 26 species representing at least 17 families. The age established by the land mammals is early Hemingfordian (early Miocene), in good agreement with the mean strontium-isotope age estimate of  $17.9 \pm 0.5$  Ma on mollusk shells. The fauna shares the greatest homotaxial similarity with the Thomas Farm Local Fauna of Florida, but also has several taxa in common with the classic early Hemingfordian faunas of the Great Plains, such as those from Quarry A of northeastern Colorado, the Runningwater Formation of western Nebraska, and the Flint Hill Quarry of southwestern South Dakota. The Pollack Farm Local Fauna provides a direct and unambiguous correlation between the North American Land Mammal Age system and marine biochronologies based on diatoms, radiolarians, foraminifers, and molluscs.

## INTRODUCTION

Although terrestrial mammals of Tertiary age have been known from eastern North America for well over a century (e.g., Leidy, 1860), the eastern record has remained poor compared to the rich faunas known from western North America. In eastern North America, Tertiary land mammals are best represented in Florida, with faunas ranging from Arikareean (about 22 Ma) to Hemphillian (about 5 Ma) (MacFadden and Webb, 1982). North of Florida, Miocene land mammals are known only from a few specimens from each of a few localities: Ashley River in South Carolina (Leidy, 1860), the Kirkwood Formation in Monmouth County, eastern New Jersey (Marsh 1870a, 1870b, 1893; Wood 1939), the Chesapeake Group of Maryland (Gazin and Collins, 1950; Wright and Eshelman, 1987), and near Statenville in extreme southern Georgia (Voorhies, 1974). Only a few of these sites represent early Miocene. Recent discovery (Ramsey et al., 1992; Benson, 1993) near Smyrna, just north of Dover, Delaware, of the most diverse assemblage of Tertiary land mammals known from eastern North America north of Florida is therefore of special importance. The assemblage, described below as the Pollack Farm Local Fauna, is early Miocene; more precisely, it is early Hemingfordian in the system of North American Land Mammal Ages (Wood et al, 1941; Tedford et al, 1987). The land mammal fossils occur in nearshore marine deposits associated with rich marine faunas, vertebrate and invertebrate, thereby affording direct, unambiguous comparison of marine and nonmarine biochronologies.

The land mammals of the Pollack Farm Local Fauna are represented predominantly by single teeth and parts of postcranial elements. In just a few instances are more than one tooth associated in a single specimen. The land mammal fauna includes a minimum of 26 species representing at least 17 families in 7 orders, summarized as follows:

### Order SORICOMORPHA

#### Family PLESIOSORICIDAE

*Plesiosorex* cf. *P. coloradensis*

### Order ERINACEOMORPHA

#### Family ?ERINACEIDAE

Unidentified genus or genera

### Order CHIROPTERA

#### Family VESPERTILIONIDAE

Unidentified genus

### Order RODENTIA

#### Family CASTORIDAE

*Anchitheriomys* sp.

"*Monosaulax*" sp.

#### Family HETEROMYIDAE

*Proheteromys magnus*

#### Family ZAPODIDAE

*Plesiosminthus* sp.

### Order CARNIVORA

#### Family URSIDAE

?*Hemicyon*

#### Family PROCYONIDAE

Unidentified genera

#### Family AMPHICYONIDAE

*Amphicyon intermedius*

*Cynelos* sp.

#### Family CANIDAE

*Tomarctus* cf. *T. thomsoni*

*Tomarctus* cf. *T. canavus*

### Order PERISSODACTYLA

#### Family EQUIDAE

*Archaeohippus* cf. *A. blackbergi*

*Anchitherium* sp.

*Parahippus leonensis*

#### Family CHALICOTHERIIDAE

cf. *Tylocephalonyx* sp.

#### Family RHINOCEROTIDAE

Unidentified genus or genera

### Order ARTIODACTYLA

#### Family TAYASSUIDAE

*Cynorca sociale*

<sup>1</sup> In Benson, R.N., ed., 1998, Geology and paleontology of the lower Miocene Pollack Farm Fossil Site, Delaware: Delaware Geological Survey Special Publication No. 21, p. 153-173.

?*Desmathyus* or *Hesperhys*  
?Family ANTHRACOTHERIIDAE  
Family OREODONTIDAE  
?Unidentified genus  
Family MOSCHIDAE  
*Blastomeryx galushai*  
Family uncertain  
Unidentified genera (probably 2)

### Acknowledgments

From the first discovery of land mammal fossils at the Pollack Farm Site through the completion of this report, an unusually large number of people have made direct and important contributions. First and foremost were the special efforts of Gordon Simonson, supervisor at the site for Pierson Engineering. Clearly two-thirds of the terrestrial mammals known to us from the site are the direct result of his efforts. Not only did he personally find many of the specimens, but with his contagious enthusiasm and spirit of volunteerism, he encouraged his fellow workers at the site to either donate their finds to the National Museum of Natural History, or to loan them for making replicas.

The following persons donated land mammal fossils to the National Museum of Natural History: David Crew, John Danner, Mike Derieux, Stuart Derrow, David Duke, Evelyne Eshelman, Keith Glunt, Michael Miskofsky, Thomas O'Hagan, Mark Power, Deborah Paruszewski, Mark Rikerson, Sandy Roberts, Gordon Simonson, Grace Simonson, Albert Snelson, Cheryl Snelson, Scott Walters, and Kenneth Webb.

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In the field aspects of this study, Dave Bohaska deserves special mention; he made a number of collecting trips to the site, and was the National Museum's primary contact with Pierson Engineering and Century Engineering and their employees, and with the many amateurs who collected much of the material. The following people from various institutions assisted in collecting: Betty Ashby, Wally Ashby, George Fonger, Vivian Marsh, Sandy Roberts, Albert Snelson, Cheryl Snelson, Curry Snelson, and Verna Muir, all of the Calvert Marine Museum Fossil Club; Joann Austin, Ruth Bowman, Diane Crow, Stephen Curtis, Allison Elterich, Charles Fithian, Libby Gregg, Alice Guerrant, Ann Horsey, Clydia Melson, Heather Patton, and James Stewart, all associated with Delaware State Museums; Lauck Ward and Cheryl Anthony of the Virginia Museum of Natural History; Edwin Crow, Ryan Crow, and Debrah Parusewski, all of Iron Hill Museum of Natural History; William Gallagher of the New Jersey State Museum; Frederick Grady, Peter Kroehler, Robert Purdy, and Clayton Ray, all from the National Museum; and, of course, Gordon Simonson.

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Frederick Grady of the National Museum processed and picked the washed matrix to recover the micromammals, which added substantially to the diversity of the collection. Peter Kroehler did the photography for the plates and assisted with preparing and curating the material.

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### METHODOLOGY

Though some of the vertebrate fossils reported herein were collected *in situ*, most were collected from the surface, either of freshly exposed *in situ* sediment, of stockpiled sediment at the site, or at places where the sediment had been used as road bed or embankment fill. We are confident that all of the specimens used in this study were derived from the lower shell bed of the Cheswold sands of the lower Calvert Formation (Benson, 1993, 1998; Ramsey, 1998). This conclusion is supported by the fact that all fossils that were discovered *in situ* were from this lower shell bed, all specimens have similar preservation, and all are consistent with a very restricted age assignment.<sup>3</sup>

Most of the material was recovered by walking or crawling over the exposed pit surfaces, spoil piles, and road bed fill surfaces. The best collecting conditions were after rains on newly stockpiled shell bed material. On some occasions buckets and shovels were used to toss water from the pit (constant pumping of the pit was necessary to keep it from filling with water) onto the outcrop faces or surfaces of spoil piles to wash matrix from fossils. Pumps with hoses, and even buckets of front end loaders, were similarly employed with good results. When a potentially good lens was encountered in place, a tool such as an oyster knife was used to carefully scrape away the surface a thin layer at a time to expose fossils.

Virtually all of the teeth of small mammals such as the heteromyid rodent and bat were recovered by screening and picking. Matrix was first screened through hardware cloth at the pit. The coarser material (about 1 cm and larger) that remained in the screen was sorted at the site; the finer material, representing about 20 percent of the original volume, was bagged and transported to the National Museum of Natural History for processing. Here the matrix was further graded

<sup>3</sup> The lower shell bed was not unearthed until winter 1991–1992. Collections made before this time could only have been from the upper shell bed.—ED

using screen with approximately 3-mm openings, and the coarser fraction was picked with unaided eyes; the finer fraction was then first sorted under a magnifying light on black background to recover otoliths and whole small invertebrates. After this initial picking, it was placed in an acidic bath to remove the fragmentary shell material, reducing this fine fraction to about 10 percent of its original volume. The residue was then picked under a binocular microscope at 10 power and high intensity light on white background, as virtually all of the teeth and bones have a very dark color. This process, though tedious and time consuming, produced about 12–14 mammal teeth from an estimated 250 kg of sediment processed.

#### Abbreviations Used

When used with measurements, AP = anteroposterior, TR = transverse. In dental notations, L = left and R = right; upper case letters refer to upper teeth, and lower case letters refer to lower teeth (e.g., M1 is the upper first molar, p3 is the lower third premolar). Acronyms preceding specimen numbers refer to institutional collections: AMNH = The American Museum of Natural History, New York; F:AM, Frick Collection, American Museum of Natural History; LACM, Los Angeles County Museum of Natural History; UCMP, University of California Museum of Paleontology, Berkeley; UF, University of Florida; UNSM = University of Nebraska State Museum, Lincoln; USNM = National Museum of Natural History (United States National Museum), Washington.

#### SYSTEMATIC PALEONTOLOGY

##### Order SORICOMORPHA Gregory, 1910

##### Superfamily SORICOIDEA Fischer de Waldheim, 1817

##### Family PLESIOSORICIDAE Winge, 1917

##### *Plesiosorex* Pomel, 1848

##### *Plesiosorex* cf. *P. coloradensis* Wilson, 1960

Material.—USNM 475857, right m1.

Discussion.—This tooth (Fig. 1A–C) corresponds closely in size to m1 of *Plesiosorex coloradensis*, and differs only slightly in morphology. In the Pollack Farm tooth, the trigonid appears to be slightly longer anteroposteriorly, relative to the talonid, because of its longer and slightly more obliquely oriented paraconid blade. With a sample of one it cannot be determined whether this difference is individual variation or species distinction, so we assign the tooth provisionally to *P. coloradensis*. Measurements of comparable molars in the sample of *P. coloradensis* from Quarry A of northeastern Colorado range from 3.9 to 4.0 mm anteroposteriorly, and from 2.5 to 2.6 mm transversely (Wilson, 1960:24). The same measurements of USNM 475857 are 3.8 mm and 2.3 mm, respectively; the latter measurement, however, is a minimum because some enamel is broken from the buccal surface of the protoconid.

##### Order ERINACEOMORPHA Gregory, 1910

##### Family ?ERINACEIDAE Fischer de Waldheim, 1817

Material.—USNM 475854, left M2 or M3; USNM 475862, trigonid of left lower molar; USNM 475858, left lower molar.

Discussion.—USNM 475854 (Fig. 1D) most closely resembles M3 of the galericine hedgehog *Lanthanotherium* (see James, 1963, figs. 13 and 16, for example). It measures

2.15 mm transversely and 2.11 mm anteroposteriorly (along buccal margin), versus 1.82 mm and 1.94 for the same measurements of *Lanthanotherium sawini*, UCMP 54600 (James, 1963, table 8). Except for its smaller size, USNM 475854 also resembles M2 of the brachyericine hedgehogs such as *Brachyerix* and *Amphechinus* (Rich, 1981); in these brachyericines, M3 has been lost and M2 has been reduced so that it superficially resembles the M3 of some other hedgehogs such as *Lanthanotherium*.

USNM 475858 is a left lower molar (Fig. 1E), so abraded that identification is not possible beyond saying that it is clearly a lower molar of tribosphenic type with distinct trigonid and talonid. USNM 475862, not illustrated, is also not identifiable beyond saying that it is the trigonid of a lower molar of hedgehog size and has the reduced paraconid typical of hedgehogs. It is doubtful that these three specimens represent one genus, and is by no means certain that they represent hedgehogs.

#### Order CHIROPTERA

##### Suborder MICROCHIROPTERA

##### Family VESPERTILIONIDAE Gray, 1821

Material.—USNM 475856, right M1 or M2. USNM 475860, trigonid of left lower molar.

Discussion.—A very small bat is represented by the M1 or M2 (Figure 1F), which measures 1.68 mm anteroposteriorly by 1.93 mm transversely; the size is comparable to that of the smaller species of *Myotis*, but in this tooth the lingual margin is rounded rather than having the angular outline seen in *Myotis*. Bats are well represented in the Thomas Farm fauna of Florida, but this tooth appears to be unlike any of those. The lower molar talonid (USNM 475860, Fig. 1G) also represents a microchiropteran bat, but is probably not further identifiable, and does not necessarily represent the same taxon as the upper molar.

#### Order RODENTIA Bowdich, 1821

##### Family CASTORIDAE Hemprich, 1820

##### *Anchitheriomys* Roger, 1898

##### *Anchitheriomys?* sp.

Material.—USNM 475897, a fragment of incisor.

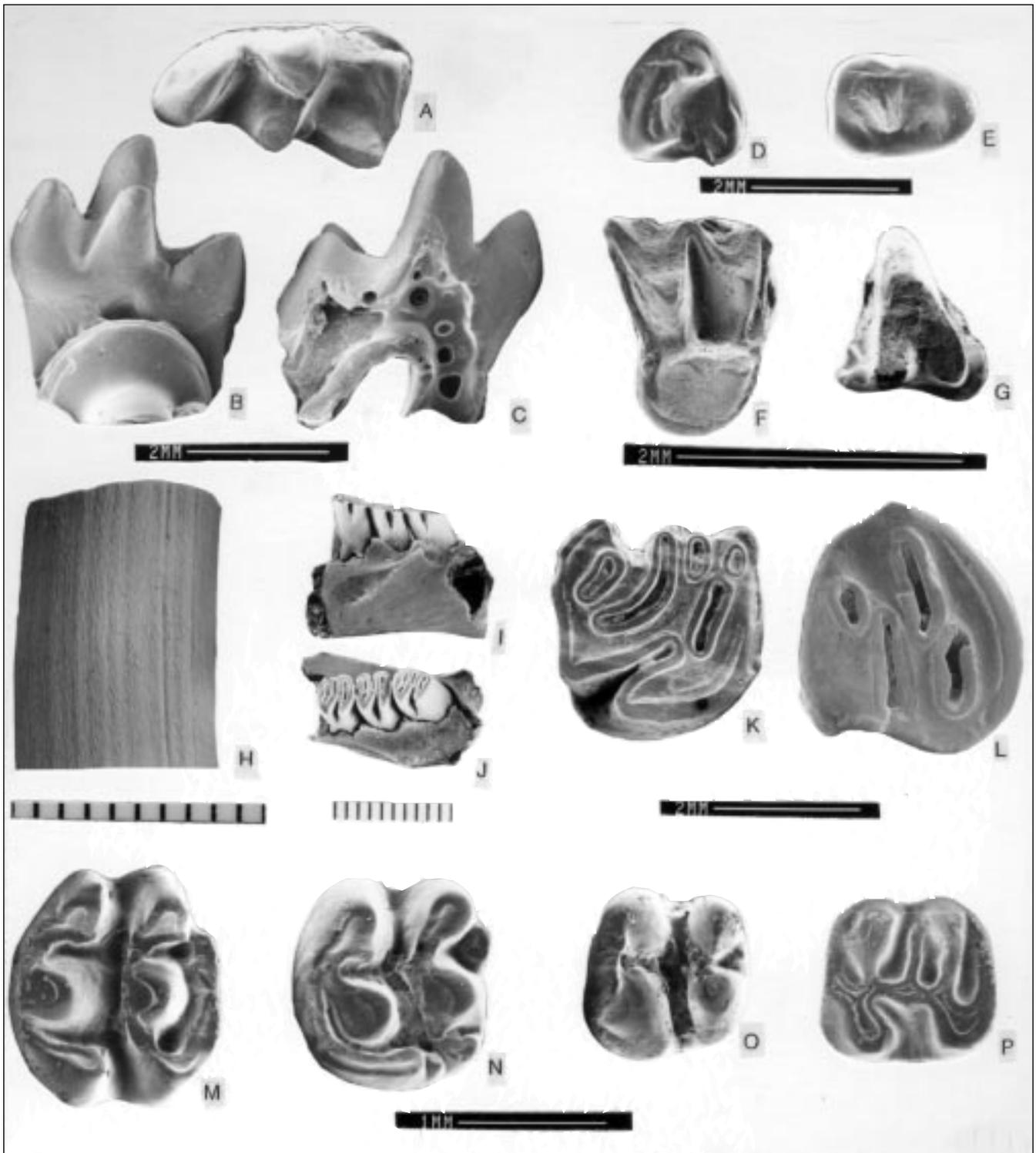
Discussion.—This specimen, which consists of a section of the anterior face of an incisor, indicates the presence in the fauna of a large rodent. The curvature, in cross section, of its anterior face and the prominent longitudinal corrugation of its enamel (Fig. 1H) are characteristic of *Anchitheriomys* (see Voorhies, 1990; Wilson, 1960). Furthermore, *Anchitheriomys* is the only rodent known from the North American early Miocene that is this large. The complete cross section of the incisor is not preserved in this specimen; the minimum transverse dimension is 8 mm.

##### “*Monosaulax*” Stirton, 1935

##### “*Monosaulax*” sp.

Material.—USNM 475818, partial left dentary with m1-m3; USNM 475836, right P4; USNM 475933, left P4 with damaged crown; USNM 475896, part of ?right m1 or m2; USNM 475863, part of incisor; 475934, cast of part of incisor in private collection.

Discussion.—Several characters of this small beaver (Figure 1I–L) place it in the “*Monosaulax*”/*Eucastor* group:



**Figure 1.** Insectivores (A–E), bats (F–G) and rodents (H–P) of Pollack Farm Local Fauna. A–C, USNM 475857, *Plesiosorex* cf. *P. coloradensis* in A, occlusal, B, lingual, and C, buccal views. D, USNM 475854, left M2 of brachyericine erinaceid or M3 of galericine erinaceid. E, USNM 475858, left molar of ?insectivore. F–G, Microchiroptera; F, USNM 475856, right M1 or M2, vesperilionid; G, USNM 475860, trigonid of left m1 or m2. H, USNM 475897, *Anchitheriomys*, fragment of incisor enamel. I–L, “*Monosaulax*” sp.; I–J, USNM 475818, left partial dentary with m1–m3, in I, buccal, and J, occlusal views; K, USNM 475836, right P4; L, USNM 475896, part of left m1 or m2. M–O, *Proheteromys magnus*; M, USNM 475855, right M1 or M2; N, USNM 475853, left m1 or m2; O, USNM 475852, right p4. P, *Plesiosminthus* sp, USNM 475851, left M2. All approximately X12.5 except for H, which is approximately X4.5 and I–J, which are approximately X2. Scales in millimeters.

in the lower cheek teeth, the protoconid and hypoconid pillars are quite angulate (Fig. 1I–J), suggesting the “rabbit pattern” that Stirton (1935) cited as characteristic of *Eucastor*; in USNM 475836, the P4 (Fig. 1K), the hypoflexus approximately equals the paraflexus, and these and the mesoflexus and metaflexus are arched anteriorly; the buccal end of the hypoflexus is opposite the lingual end of the paraflexus. This P4 (USNM 475836) has two additional fossettes, which Xiaofeng Xu (personal communication, 1993) considers a plesiomorphic character common in earlier beavers, including Arikareean forms such as *Palaeocastor* and *Capacikala*. The Pollack Farm beaver differs from typical *Palaeocastor*, however, in the other characters mentioned above, as well as in the cross sectional shape of its incisors, which have rounded anterior faces rather than flat.

Voorhies (1974) reported the first known Tertiary record of Castoridae in eastern North America, a single tooth from southern Georgia referred to cf. “*Monosaulax*” and dated as Barstovian by means of associated teeth of *Merychippus*. We follow Voorhies (1990) in placing the name “*Monosaulax*” within quotation marks, because of the uncertain status of its type species, *M. pansus* (Cope). Stout (in Skinner and Taylor, 1967), for example, offered an opinion, without the supporting justification, that *M. pansus* is a junior synonym of the type species of *Eucastor*, *E. tortus* Leidy, 1858. Xiaofeng Xu (personal communication, 1993) also considers *Monosaulax* a junior synonym of *Eucastor*.

Measurements of the cheek teeth of USNM 475818, taken at the occlusal surface are: m1, AP=3.3 mm, TR=3.7 mm; m2, AP=3.3 mm, TR=3.6 mm; m3, AP=3.6 mm, TR=3.6 mm. USNM 475836, a P4, is AP=3.1 mm, TR = approximately 3.2 mm (buccal edge is broken so this measurement is inexact) at the occlusal surface. These measurements indicate that this small beaver is within the size range of *Monosaulax* from Quarry A of northeastern Colorado, discussed by Galbreath (1953) and Wilson (1960). Wilson (1960) referred to the Quarry A material as “*Monosaulax* n. sp.” and provided a description and measurements, but refrained from naming the species “in deference to Thompson Stout’s forthcoming work on the Castoridae of the World,” which remains unpublished. Identification of the Delaware material to specific level, if indeed possible, should be done in the context of a broader study of the generic group. Suffice it to say here that it represents a small and relatively plesiomorphic species of “*Monosaulax*,” which is most likely a junior synonym of *Eucastor*.

#### Family HETEROMYIDAE Allen and Chapman, 1893

##### *Proheteromys* Wood, 1932

##### *Proheteromys magnus* Wood, 1932

Material.—USNM 475855, RM1 or M2; USNM 475853, Lm1 or m2; USNM 475852, Rp4.

Discussion.—The original material of *P. magnus*, including its holotype, is from the Thomas Farm Fauna of Florida (Wood, 1932). Several teeth from Quarry A of northeastern Colorado were referred to the same species by Wilson (1960). The three teeth from the Pollack Farm Site (Fig. 1M–O) are assigned to *Proheteromys magnus* primarily on the basis of size, but Black’s (1963) emended diagnosis for the species also includes several characters that apply here: “largest species of genus; central valley completely

bisects upper molars; p4 with median crest; anteroconid present on p4; stylids small on lower molars; posterior cingulum short but prominent on lower molars.”

The upper molar, USNM 475855, measures 1.44 mm anteroposterior, by 1.79 mm transversely; the upper molar of *P. magnus* from Thomas Farm measures, respectively, 1.5 mm, by 1.8 mm (Black, 1963:500). The M1 or M2 referred from Colorado is slightly smaller; the same measurements are, respectively, 1.25 mm and 1.60 mm (Wilson, 1960:80).

The lower molar, USNM 475853, measures 1.44 mm anteroposteriorly and 1.57 mm transversely. The sample of *P. magnus* from Thomas Farm is respectively, 1.53 mm (mean, N = 3) by 1.56 mm (mean, N = 3) (Black, 1963:500).

The p4, USNM 475852, measures 1.28 mm anteroposteriorly by 1.23 mm transversely. The same measurements of the Thomas Farm p4 are 1.4 mm by 1.4 mm (Black, 1963:500), and of a Colorado specimen are 1.4 mm by 1.2 mm (Wilson, 1960:80).

Though these three teeth from Delaware conform to the emended diagnosis of *P. magnus* given by Black (1963), there are some morphologic differences between them and the Florida and Colorado specimens that may be worth noting (see Lindsay, 1972:40, fig. 19 for heteromyid dental terminology). In the upper molar, USNM 475855 (Fig. 1M), the anterior cingulum is stronger, extending from the protostyle across the anterior margin of the tooth to meet the base of the paracone, enclosing two small basins between it and the protoloph (compare Fig. 1M with Black, 1963, fig. 5b, and with Wilson, 1960, fig. 123). In these characters, this upper molar bears considerable resemblance to *Proheteromys* sp. from the Harrison Formation of Nebraska (Korth, 1992, fig. 13A); the Nebraska specimen is substantially smaller, however. In the lower molar, USNM 475853 (Fig. 1N), the anterior cingulid, which ends in the protostylid, seems to extend slightly farther posteriad, and between the protostylid and hypostylid is a very small separate cusp; this more posteriorly placed protostylid, along with the small, separate cusp, block the transverse valley so that it does not open on the buccal side of the tooth, as it appears to do on the Florida specimen (compare Fig. 1N with Black, 1963, fig. 5e). The Pollack Farm tooth is suggestive of some specimens of *P. sulculus*, in which the anterior cingulid, protostylid and hypostylid appear to be connected in one continuous crest (see for example Wilson, 1960, fig. 108). These molars of *P. sulculus*, however are 25 to 30 percent smaller than the tooth from Delaware and others referred to *P. magnus*.

#### Family ZAPODIDAE Coues, 1875

##### Subfamily SICISTINAE Allen, 1901

##### *Plesiosminthus* Viret, 1926

##### *Plesiosminthus* sp.

Material.—USNM 475851, left M2.

Discussion.—One isolated but distinctive tooth (Fig. 1P) represents a small species of *Plesiosminthus*. The tooth is very low crowned; the slight wear has not obscured details of morphology. A species assignment is probably not possible on the basis of this single tooth. It is of appropriate size to be *P. galbreathi* Wilson, 1960, and, as in this species and also in *P. clivosus* Galbreath, 1953, the endoloph is connected to the protocone (see Green, 1977:997 for terminology); in other species, *P. grangeri* (Wood, 1935) and *P. sabrae* (Black, 1958), the endoloph normally stops short of

the protocone (see Green, 1977:1001, fig. 3, for example). In the Pollack Farm tooth the mesoloph is long, reaching nearly to the buccal margin of the tooth; its buccal end is associated more directly with the metacone than with the paracone.

USNM 475851 measures 1.27 mm anteroposteriorly and 1.18 mm transversely. No upper second molars of *P. clivosus* were reported from Quarry A of northeastern Colorado, but Wilson (1960:85) gave mean measurements of 1.4 mm (anteroposterior) and 1.2 mm (transverse) for *P. galbreathi*. Green (1977) referred specimens from the Batesland Formation of South Dakota to *P. clivosus*; he reported mean values of 1.04 mm and 0.89 mm for the same respective measurements, somewhat smaller than *P. galbreathi* and the Pollack Farm tooth. In summary, the Delaware tooth represents a small primitive *Plesiosminthus*, which in size and morphology is comparable to the species that occur in early Hemingfordian deposits of the western Great Plains and Rocky Mountain areas.

**Order CARNIVORA Bowdich, 1821**  
**Family URSIDAE Fischer de Waldheim, 1817**  
**Subfamily HEMICYONINAE Frick, 1926**

**?*Hemicyon* Lartet 1851**

Material.—USNM 475830, distal end of left radius.

Discussion.—The specimen (Fig. 2A–B) represents a relatively large carnivore. It is slightly abraded, but the measurements of 45 mm for the greatest width and 24 mm for the depth are close to its original size. It is about two-thirds the size of a radius of *Amphicyon* (UF 95032) from Thomas Farm, and differs in morphologic details, which are more suggestive of a bear. Our tentative referral of this distal radius to *Hemicyon* is circumstantial: it is of appropriate size to be a radius of the ursid *Hemicyon*; the Pollack Farm fauna and Thomas Farm fauna are otherwise largely homotaxial; *Hemicyon* occurs in the Thomas Farm fauna (Tedford and Frailey, 1976); so *Hemicyon* would not be unexpected in the Pollack Farm fauna.

**Family PROCYONIDAE Gray, 1825**  
**Subfamily PROCYONINAE Gray, 1825**

Material.—USNM 475815, right M1.

Discussion.—The M1 (Fig. 2C) is reminiscent of that of *Edaphocyon*, but differs in having a more nearly isolated metaconule. Except for its much smaller size, it is most like an undescribed tooth from Sucker Creek, Oregon (comparison made with AMNH 105117, a cast of LACM 1771).

**Subfamily BASSARISCINAE Gray, 1869**

Material.—USNM 475814, posterior part of right mandibular ramus with alveoli for m2.

Discussion.—The jaw fragment (Fig. 2D–E), represents a smaller animal than the molar mentioned above. The posterior alveolus is anteroposteriorly elongate, indicating the presence of an elongate m2, which is characteristic of procyonids. This fragment is of similar size, and otherwise compares well with a small *Bassariscus*-like form represented by two partial jaws in the Frick Collection (AMNH) from Cottonwood Creek Quarry (Hemingfordian) in western Nebraska (the Frick specimens are not cataloged but have “Hay Springs” field numbers 396-2828 and 397-2930).

**Family AMPHICYONIDAE Haeckel, 1866**  
***Amphicyon* Lartet, 1836**

***Amphicyon intermedius* White, 1940**

Material.—USNM 475816, left m1; USNM 475916, cast of right m2 in private collection; USNM 475917, cast of trigonid of right m1 in private collection; USNM 475829, left scapholunar.

Discussion.—Close correspondence is found between these teeth (Fig. 2F–H) and those of *Amphicyon intermedius* from the Thomas Farm of Florida. The m2 (USNM 475916, Fig. 2F), although well worn, nevertheless shows a distinct metaconid, as is also seen in the same tooth of MCZ 3631 (comparison with cast in AMNH), the type of *A. intermedius*, a left mandibular ramus with p3-m2 (White, 1940: pl. III). The width of the Pollack Farm m2 is 16.7 mm, versus 14.5 mm in MCZ 3631 (White, 1940:32).

The Pollack Farm m1 (USNM 475816, Fig. 2G–H) measures 27.8 mm anteroposteriorly and 13.9 mm transversely, very close to the size of m1 in the type of *A. intermedius*, MCZ 3631 (29 mm anteroposteriorly, 14 mm transversely), and also to m1 in MCZ 3630 (29 mm anteroposteriorly, 13.5 mm transversely), a right mandibular ramus with p3-m1. The Pollack Farm m1 appears to be equal in size to an unworn m1, UF 95013, and noticeably smaller than MCZ 5833, both of which are also from Thomas Farm. The entoconid of the Delaware m1 is slightly less distinct than on the Florida specimens, but the morphology is otherwise very similar. The size disparity (i.e., the m1 is equal to or slightly smaller than in Thomas Farm material, while the m2 is larger), is not great enough to suggest more than one species; sexually dimorphic size disparity in these larger amphicyonids is well documented (Ginsburg, 1961; Ginsburg and Telles Antunes, 1968; R. M. Hunt, personal communication, 1994).

The scapholunar, USNM 475829, is morphologically similar to several in the University of Florida collections (e.g., UF 95024, 95025, 67222), although it is substantially smaller. Its reference to *A. intermedius* is not certain, but it does seem to be too large to belong to the smaller amphicyonid *Cynelos* discussed below.

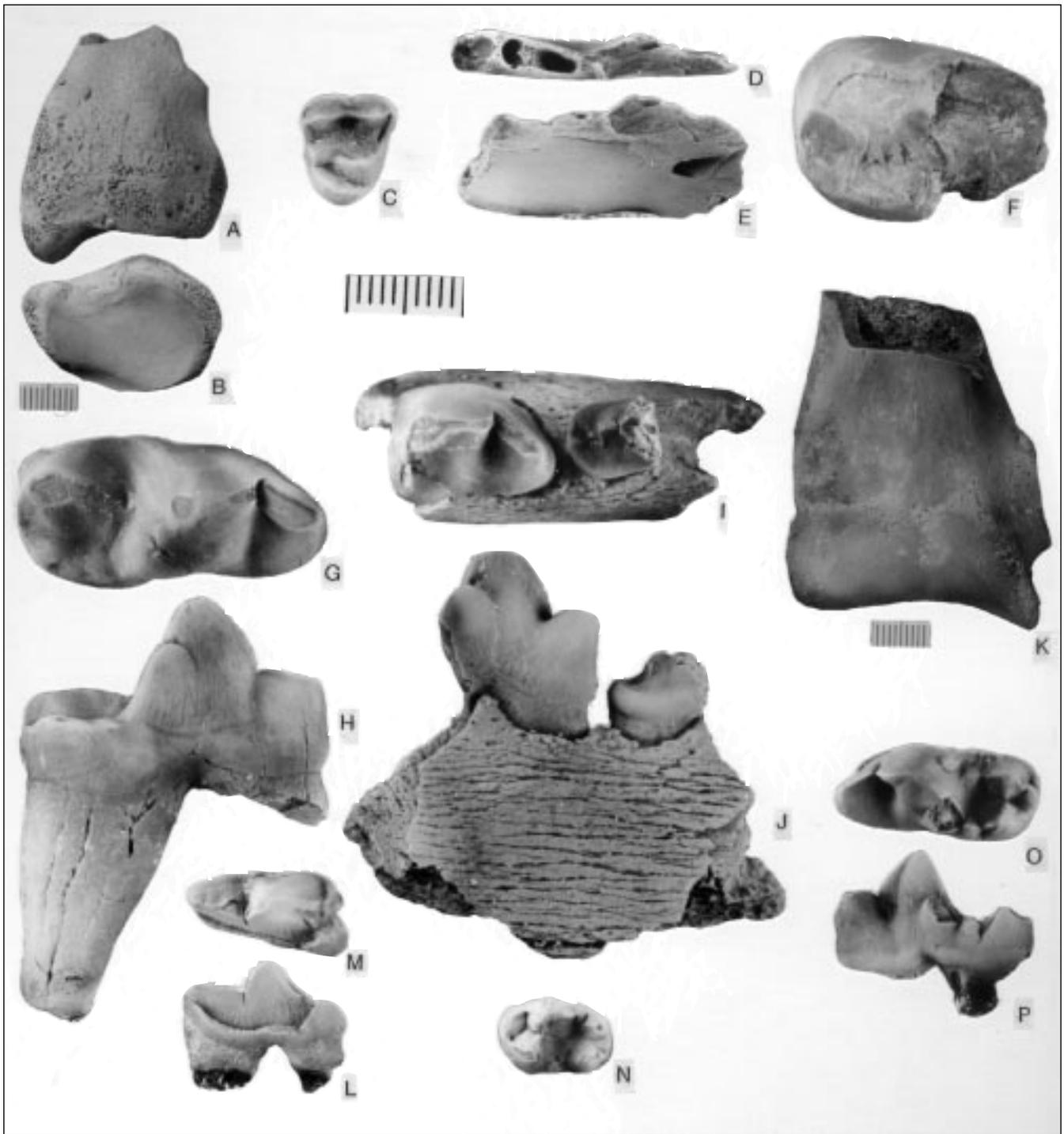
***Cynelos* Jourdan 1848**

***Cynelos* sp.**

Material.—USNM 475811, left jaw fragment with posterior half p4 and anterior half m1; tentatively referred, USNM 475918, cast of distal end of right humerus in private collection.

Discussion.—In USNM 475811 (Fig. 2I–J) the paraconid of m1 is shorter and oriented more obliquely than it is in *Amphicyon*, and the posterior surface of the trigonid is squared off and oriented more nearly transversely. Enough of the p4 remains to show that it had a distinct posterior accessory cuspid. In all parts remaining for comparison, the specimen corresponds very closely, both in size and morphology, to UNSM 25675 (comparisons with cast in AMNH), identified as *Cynelos* sp., from the lower part of the Marsland Formation of western Nebraska.

The distal portion of a right humerus (Fig. 2K) is clearly from an amphicyonid carnivore. The entepicondylar foramen is retained in amphicyonids, and although the medial and lateral epicondyles are broken and abraded in this spec-



**Figure 2.** Carnivores of Pollack Farm Local Fauna. A–B, Ursidae, *?Hemicyon* sp., USNM 475830, distal end of radius in A, anterior, and B, distal views. C–E, Procyonidae; C, USNM 475815, right M1 of procyonine, ?genus. D–E, USNM 475814, part of right mandible of bassariscine, ?genus, in D, alveolar, and E, lingual views. F–K, Amphicyonidae; F, USNM 475916, *Amphicyon intermedius* incomplete right m2; G–H, USNM 475816, *Amphicyon intermedius* left m1 in G, occlusal, and H, lingual views; I–J, USNM 475811, *Cynelos* sp., mandibular fragment with parts of p4 and m1, in I, occlusal, and J, lingual views; K, USNM 475918, *?Cynelos* sp., distal end of right humerus. L–P, Canidae; L, USNM 475812, *Tomarctus* cf. *T. thomsoni*, right P4 in L, lingual, and M, occlusal views; N–P, *Tomarctus* cf. *T. canavus*; N, USNM 475930, left m2; O–P, USNM 475817, right m1 in O, occlusal, and P, lingual views. All approximately X2, except K, which is approximately X1. Scales in millimeters.

imen, enough remains to demonstrate that an entepicondylar foramen was present. A humerus of *Amphicyon* from Thomas Farm, Florida (UF/FSG 6334) is morphologically identical to the Delaware humerus, except that it is nearly twice the size. The Delaware specimen is therefore assigned to *Cynelos*, which is substantially smaller than *Amphicyon* and the only other amphicyonid presently known in the assemblage.

**Family CANIDAE Fischer de Waldheim, 1817**

***Tomarctus* Cope, 1873**

***Tomarctus* cf. *T. thomsoni* (Matthew, 1907)**

Material.—USNM 475812, right P4.

Discussion.—A small species of Caninae is represented by an upper carnassial (Fig 2L–M) that is virtually identical to P4 in the type of *Tomarctus thomsoni* (originally *Cynodesmus thomsoni* Matthew, 1907) (compare Fig. 2L–M with Matthew 1907, fig. 5). USNM 475812 is 13 mm from the most anterior part of its paracone to the most posterior part of the metacone, the same size as that given by Matthew (1907, p. 188) for P4 of *T. thomsoni*.

***Tomarctus* cf. *T. canavus* (Simpson), 1932**

Material.—USNM 475817, right m1; USNM 475930, cast of left m2 in private collection; USNM 475832, right c1.

Discussion.—The lower molars, m1 and m2 (Fig. 2N–P) are at least 20 percent larger than the same teeth of *T. thomsoni* (m1 is 17.5 mm anteroposteriorly, and m2 is 10.5 mm anteroposteriorly, versus 14.5 mm and 7.5 mm, respectively, in *T. thomsoni*). These teeth are most similar to Thomas Farm *Tomarctus canavus* specimens such as UF 94868, 19952, and especially to the unworn right m1 of UF 5658. This m1 and m2 are both slightly larger than the same teeth of the type of *T. canavus*; measurements given by Simpson (1932:20) are 16 mm AP and 7 mm TR for m1, and 9 mm AP by 6 mm TR for m2; The Delaware m1 is 17.5 mm AP by 7.6 mm TR, and the m2 is 10.5 mm AP by 6.3 mm TR. The morphology is very close, however (compare Fig. 2O–P with Simpson, 1932, fig. 4). In the Delaware specimen, the talonid basin forms a distinct cross or plus sign, as it does also in the Thomas farm specimens of *T. canavus*. These Pollack Farm teeth are also closely comparable to specimens identified as *Tomarctus* sp. in the AMNH collections from the Runningwater Formation of western Nebraska.

**Order PERISSODACTYLA Owen, 1848**

**Family EQUIDAE Gray, 1821**

***Archaeohippus* Gidley, 1906**

***Archaeohippus* cf. *A. blackbergi* (Hay, 1924)**

Material.—USNM 475782, left M1 or M2; 475783 left M1 or M2; 475777, left M1 or M2; 475776, left ?P4, missing most of ectoloph; USNM 475911, cast of right ?P4 in private collection; USNM 475910, cast of right P2 in private collection; 475792, ectoloph of right upper cheek tooth; USNM 475781, left m1 or m2; USNM 475915, cast of left p3 or p4 in private collection; USNM 475913, cast of right m1 or m2 in private collection; USNM 475914, cast of anterior half of left lower cheek tooth from private collection; 475796, distal end of left humerus; 475797, proximal end of right radius; 475806, proximal half right ulna; 475795, distal

**Table 1**

Measurements in millimeters of teeth of *Archaeohippus* cf. *A. blackbergi* from Pollack Farm Local Fauna. AP = anteroposterior, TR = transverse, CR = crown height at unworn paracone.

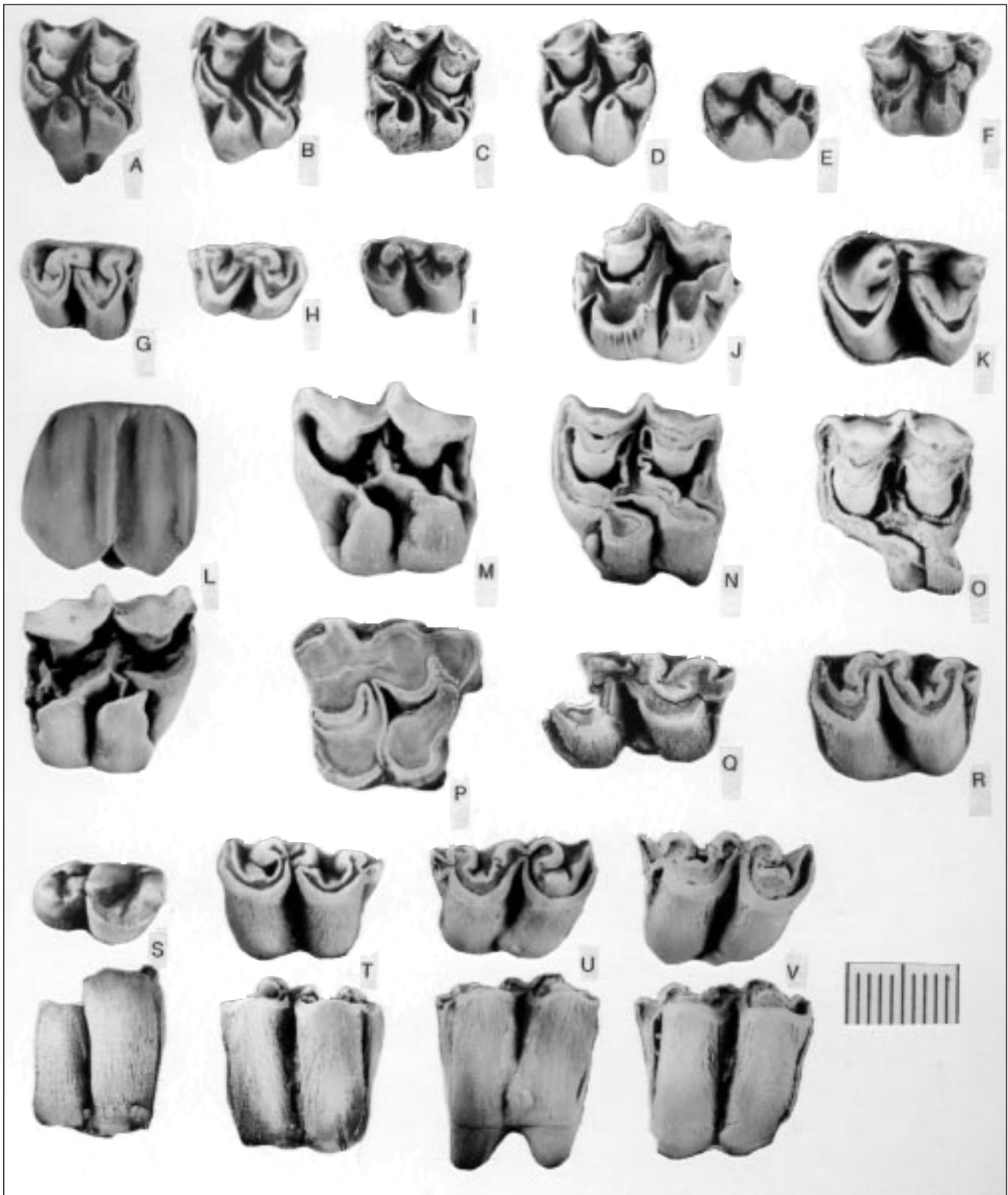
SPECIMEN	AP	TR	CR
USNM 475782, M1 or M2	11.1	13.0	—
USNM 475783, M1 or M2	10.7	12.9	—
USNM 475777, M1 or M2	0.5	12.1	—
USNM 475911, ?P4	11.0	12.9	8.1
USNM 475910, P2	11.5	10.1	—
USNM 475915, p3 or p4	11.1	9.2	—
USNM 475781, m1 or m2	9.9	6.6	—
USNM 475913, m1 or m2	10.2	6.5	—

end right radius; 475799, right astragalus; 475810, right partial astragalus; 475794, distal end of metapodial; 475804, distal end of metapodial.

Discussion.—The small species of *Archaeohippus* represented by these teeth and parts of postcranial elements was one of the more common elements of the fauna. These teeth are slightly smaller than those referred to *A. blackbergi* from Thomas Farm of Florida, although the upper end of the size range of the Pollack Farm teeth overlaps the lower end of the size range of the Florida sample (see Table 1 for measurements; compare with White, 1942, fig. 2). Morphologically they are very similar to some of the Florida specimens (UF 43620 for example), but also differ in some characters, or at least in the consistency of characters, from many of the Florida specimens.

In the six well-preserved upper teeth from the Pollack Farm Site (Fig 3A–F), the metaloph connects to the ectoloph in all but the P2; this seems also to be the condition in *A. blackbergi*. No crochet is present in any of the six Pollack Farm teeth that permit this determination; White (1942, fig. 2) indicates a crochet in more than half the molars and premolars of Thomas Farm *A. blackbergi*. None of the Pollack Farm teeth has any plications on the metaloph; plications are present on about one third of the Florida teeth of *A. blackbergi*. In the six well preserved upper teeth from Pollack Farm, the protocones are distinct from the protoconule (especially evident on the unworn tooth, USNM 475776, Fig. 3E), and distinct constrictions separate the hypocones from metaconules; in most Thomas Farm *A. blackbergi* the protocones are somewhat less distinct and the hypocones are not at all distinct within the metaloph. The Pollack Farm teeth all have a narrow crest extending from the posterior cingulum near the metastyle, diagonally toward the metaloph, closing off the postfossette; White (1942:19) termed this structure the hypoloph, and noted its presence in many teeth of Thomas Farm *A. blackbergi*, particularly in the premolars. In the Pollack Farm teeth this hypoloph usually joins the metaloph near or at the junction of metaconule and hypocone.

White (1942) demonstrated that the sample referred to *A. blackbergi* (White considered it *Parahippus blackbergi*) from Thomas Farm of Florida has a 16 percent variation in size, that all of the tooth characters were also extremely variable, but that the different character states were not associated in any consistent way that would permit separation into more than one species. Bader (1956) conducted a quantitative study of the Thomas Farm equidae and found that while tooth characters are variable, those of *A. blackbergi* were



**Figure 3.** Equidae of Pollack Farm Local Fauna. A–I, *Archaeohippus* sp.; A, USNM 475782, left M1 or M2; B, USNM 475783, left M1 or M2; C, USNM 475777, left M1 or M2; D, USNM 475911, right ?P4 ; E, USNM 475776, part of left ?P4; F, USNM 475910, right dP2; G, USNM 475915, left p3 or p4; H, USNM 475913, right m1 or m2; I, USNM 475781, left m1 or m2. J–K, *Anchitherium* sp.; J, USNM 475775, right P2 missing ectoloph and parastyle; K, USNM 475780, left m1 or m2. L–V, *Parahippus leonensis*; L, USNM 475784, right M2 in buccal (above) and occlusal (below) views; M, USNM 475908, left ?M2; N, USNM 475906, left M1; O, USNM 475788, incomplete left dP3 or dP4; P, USNM 475907, right P2; Q, USNM 475778, left dp3; R, USNM 475903, left p4; S, USNM 475905, incomplete right m3, in occlusal (above) and buccal (below) views; T, USNM 475904, left m1 or m2, in occlusal (above) and buccal (below) views; U, USNM 475902, right m1 or m2, in occlusal (above) and buccal (below) views; V, USNM 475785, right m2. All approximately X2. Scale in millimeters.

comparable to other species of the genus.

We assign the Pollack Farm *Archaeohippus* tentatively to *A. blackbergi*, but emphasize that this species as presently constituted may include more than one species.

#### ***Anchitherium* von Meyer, 1844**

##### ***Anchitherium* sp.**

Material.—USNM 475775, right P2 missing ectoloph and parastyle; USNM 475780, left lower molar with posterior end missing.

Discussion.—These teeth (Fig. 3J-K) are of the same general size as, or perhaps slightly larger than, the *Parahippus* teeth discussed below, but clearly belong to a more primitive horse with lower crowned teeth. The P2 (Fig. 3J) is missing so much of the buccal portion that no standard measurements can be recorded; it is 14 mm from the posterior edge of the hypostyle to the anterior edge of the protoconule. The metaloph is connected to the ectoloph. Along the lingual margin, especially at the base of protocone and hypocone, is a heavy basal shelf; this shelf does not have a well defined edge as would be expected with an internal cingulum, but the present appearance may be due to post mortem abrasion.

USNM 475780 (Fig. 3K) is identified as a lower molar, rather than premolar, because the anterior part of the tooth is broader than the posterior part. The metaconid-metastylid column is connate in lingual view; the metaconid is distinct and slightly separated from the metastylid. No parastylid is developed; the paralophid simply descends lingually and turns backward toward the base of the metaconid. In size and morphology this lower molar is comparable to m1 or m2 of larger species of *Miohippus*, such as *M. validus*, but also resembles smaller species of *Anchitherium* such as *A. agatensis* and *A. clarencei*. The maximum width of the tooth, 12.7 mm, is from the lingual margin to the buccal base of the protoconid. If this tooth is m1 or m2, it is slightly smaller, and if m3 somewhat larger, than those teeth in the mandible (FSGS V-5423) from Thomas Farm of Florida referred by Simpson (1932) to *Anchitherium clarencei*, which have widths of 14.5 mm and 13.5 mm, and 11.5 mm, respectively. As in *A. clarencei*, this tooth has a distinct external cingulum and no internal cingulum.

These two teeth, neither of which is complete, are probably not sufficient basis for confident specific identification, but they surely represent an anchitherine horse, which we tentatively consider a small species of *Anchitherium*.

#### ***Parahippus* Leidy, 1858**

##### ***Parahippus leonensis* Sellards, 1916**

Material.—USNM 475784, unworn right M2; USNM 475908, cast of left unworn ?M1 in private collection; USNM 475906, cast of slightly worn left M1 in private collection; USNM 475907, cast of worn right P2 in private collection; USNM 475788, left DP3 or DP4, worn; USNM 475909, cast of P3 or P4, lacking ectoloph, in private collection; 475786, tooth fragment consisting of paracone and mesostyle; USNM 475902, cast of right m1 or m2 in private collection, slightly worn; USNM 475904, cast of left m1 or m2 in private collection, slightly worn; USNM 475903, cast of left p4 in private collection, moderate wear; USNM 475785, right m2, slight wear; USNM 475788, left dp3,

deciduous premolar, moderate wear; USNM 475905, cast of right m3, missing trigonid, from private collection; USNM 475787, trigonid of right lower cheek tooth, slight wear; USNM 475808, right astragalus; USNM 475790, left astragalus; USNM 475789, right calcaneum; USNM 475793, partial right calcaneum; USNM 475809, distal part of metapodial; USNM 475802, left navicular; USNM 475791, distal end left femur.

Discussion.—This material (Fig. 3L-V) represents a small species of *Parahippus* that has, compared to other *Parahippus*, a combination of primitive and advanced characters. For dental terminology used here, see MacFadden (1984:17, fig. 4). In one of the two unworn teeth, USNM 475784, the protocone is separated by a notch from the protoconule, whereas a sharp crest is continuous from protoconule to protocone in the other; with slight wear the protoconule and protocone are invariably linked. In these unworn teeth, shallow notches separate the crochet from the protoloph and the hypostyle from the hypocone, but with slight wear the prefossette and the postfossette become completely isolated. In the two unworn teeth, the protoconule-protocone connection appears to be higher than the crochet-protoloph connection, and the hypostyle-metaloph connection is even more imperfectly formed. The hypocone is strongly united to the metaconule in all specimens. At least two pli prefossettes and two pli postfossettes are developed on the metaloph on the few specimens where this can be determined. The pli caballin is absent on USNM 475906, barely indicated on USNM 475908, and prominent on USNM 475784. No cement is seen on any of the teeth, with the possible exception of USNM 475909, which might have a very thin coat of cement in the fossettes and on the anterior surface of the protoloph. The hypostyle is quite complicated, with at least one plication extending into the postfossette, and in the unworn tooth, USNM 475784, it is star-shaped. The metaconid and metastylid are distinctly separated in the lower teeth.

**Table 2**

Measurements in millimeters of elements of *Parahippus leonensis* from Pollack Farm Local Fauna. AP = anteroposterior, TR = transverse, CR = crown height of unworn teeth at mesostyle.

SPECIMEN	AP	TR	CR
USNM 475784, right M2	15.9	17.4	14.1
USNM 475906, left M1	15.0	17.1	—
USNM 475908 left ?M1	16.6	18.8	13.5
USNM 475907 right P2	16.5	15.9	—
USNM 475902 right m1 or m2	15.0	9.8	—
USNM 475903 left p4	16.0	11.6	—
USNM 475904 left m1 or m2	14.9	10.4	—
USNM 475785 right m2	16.2	10.1	—
USNM 475789 Right calcaneum maximum length, 58.4 mm			
USNM 475809 Distal metapodial, max width across trochlea, 18.5 mm			

Measurements are given in Table 2.

Morphologically, these teeth closely resemble the type of *Parahippus leonensis* Sellards, and in measurements and crown height, the holotype falls within the range of the present sample. Teeth in the sample referred to *Parahippus leonensis* from the Thomas Farm of Florida (Simpson, 1930, 1932) are also morphologically similar to the Pollack Farm

specimens in most respects, but differ in minor ways. Compared with Thomas Farm *P. leonensis*, the Pollack Farm teeth have less cement, but slightly greater expansion and separation of the metaconid-metastylid, and are perhaps slightly more advanced in the degree of connection between crochet and protoloph.

These Pollack Farm teeth are very similar to teeth from the Runningwater Formation of Nebraska in the American Museum of Natural History collections referred to *Parahippus leonensis*. Close comparisons are also seen with specimens of *Parahippus* from the Flint Hill fauna of South Dakota. The left M1, USNM 475908, appears to be morphologically identical to, though slightly larger than, the M1 of UCMP 32352 (comparison with cast in AMNH), from the Flint Hill Fauna of South Dakota, while other teeth from Flint Hill (UCMP 32353 for example) are slightly larger than the teeth from Delaware. A minor difference between the Delaware and Flint Hill specimens is that in the former the crochet-protoloph connection is more nearly complete.

This Pollack Farm *Parahippus*, like some specimens of *P. leonensis* from Thomas Farm, Florida, approaches *Merychippus* in some aspects of its morphology (near isolation of pre- and postfossettes, for example). In other features, such as virtual lack of cement, it is closely comparable to *Parahippus* known from other localities dated as early Hemingfordian. Referral to *Parahippus leonensis* seems most reasonable because of close similarity to the type.

#### Superfamily CHALICOTHERIOIDEA Gill, 1872

##### Family CHALICOTHERIIDAE Gill, 1872

##### cf. *Tylocephalonyx* Coombs, 1979

Material.—USNM 475848, an incomplete left upper molar; USNM 475843, left P3 or P4, lacking anterior cingulum; USNM 475838, cast of left metatarsal III, in private collection; USNM 475850, a left phalangeal duplex (the coossified proximal and medial phalanges of digit II of the manus); USNM 475849, distal phalanx; USNM 475935, incomplete distal phalanx.

Discussion.—These elements are so characteristic that familial allocation, to Chalicotheriidae, is without question; closer determination is less certain. The left upper molar (USNM 475848, Fig. 4A), missing part of the lingual margin and much of the ectoloph, is either M1 or M2. The anteroposterior length of the part preserved is 37.9 mm. If this tooth is M1, it would appear to be within the size range either of *Moropus elatus* (see measurements given by Coombs, 1978:15, table 1) or of *Tylocephalonyx skinneri* (see Coombs, 1979:16, table 2); if it is M2, it is somewhat smaller than *M. elatus* and *M. hollandi*, and approximately the size of *M. oregonensis*. Coombs (1979:20, table 4) compared dental characters of several species of chalicotheres. The Pollack Farm tooth has several of these characters, suggesting that it represents *Tylocephalonyx* rather than *Moropus*: the height of the posterior cingulum at the postfossette is strong (Coombs character 2), the height of the lingual cingulum just posterior to the protocone is strong (Coombs character 3), and the unworn protocone is blunt (Coombs character 6) and crescentic (Coombs character 11). The lingual cingulum posterior to the protocone, in addition to being prominent, is directed toward the anterior face of the hypocone, whereas in *Moropus* this cingulum appears to curve lingually to merge with the lingual base of the

hypocone. The result of this difference is that in *Tylocephalonyx* the hypocone extends linguad beyond this cingulum, and in *Moropus* the cingulum is the most lingual part of the tooth.

The premolar (USNM 475843, Fig. 4B) is unworn (was perhaps unerupted) and well preserved, except that the anterior cingulum has been broken away. Nevertheless, it is probably not possible to determine whether it is P3 or P4. Coombs (1979) remarked that in both *Moropus* and *Tylocephalonyx*, P3 and P4 are very similar to each other morphologically and differ but slightly in size. In this premolar (Fig. 4B), the paracone is the largest cusp, and with the metacone forms a weakly W-shaped ectoloph. Protoloph and metaloph are complete; near its junction with the paracone, the protoloph is raised into a small cusp, which is at least topographically a protoconule. The protoloph merges with the anterior surface of the protocone; the apex of the protocone is posterior to this junction. The metaloph is nearly parallel to the protoloph, and at its lingual end it turns anteriorly to merge with the posterior surface of the protocone. The anterior cingulum is broken from the tooth. The lingual cingulum is strong and continuous, and merges with the posterior cingulum at the point where the posterior cingulum is raised into what could be termed a hypostyle, which connects with the crest of the metaloph. In general, this tooth seems to be more similar to P3 and P4 of *T. skinneri*, which Coombs (1979:16) describes as “much closer to square-shaped than corresponding teeth of *Moropus elatus*.” Also, in these premolars of *Moropus*, the protoloph and metaloph tend to converge toward the protocone, whereas in *Tylocephalonyx* the lophs are more nearly parallel. USNM 475843 measures 21 mm anteroposteriorly and 23.6 mm transversely; these are within the ranges of measurements given by Coombs (1979, table 2) for P3 of *T. skinneri*; the transverse dimension is smaller than any recorded by Coombs for P4 of *T. skinneri*.

The left third metatarsal (USNM 475838, Fig. 4E) is from a fully adult animal and is well preserved. It is morphologically very similar to AMNH (FAM) 54915, the corresponding element of *T. skinneri* (see Coombs, 1979, fig. 24C–D), except that it is substantially shorter, and appears to be relatively more robust. Its greatest length is 92.7 mm, greatest distal width 37.4 mm, and minimum shaft width is 26.8 mm. The range of lengths cited by Coombs (1979, table 8) for *T. skinneri* is 104.7 mm to 131.7 mm; the shortest of these is about 13 percent larger than the Pollack Farm metatarsal. In the Pollack Farm specimen the quotient of length divided by distal width is 2.48 and of length divided by minimum shaft width is 3.45. Comparing these numbers to those in Coombs’s Table 8 (1979), shows that the Pollack Farm metatarsal is slightly more robust than the most robust *T. skinneri*, and much more robust than any comparable *Moropus elatus*. Coombs (1979) noted that a third metatarsal from the middle Hemingfordian Split Rock Fauna of central Wyoming differs from other (latest Hemingfordian) specimens of *T. skinneri* in two important ways: it has, between the proximal (ectocuneiform) facet and the facet for metatarsal IV, a narrow strip of articular surface, apparently for the cuboid (this facet is not present in other specimens), and the dorsal and volar parts of its metatarsal IV facet are confluent (separated by a trough in other specimens). Both these conditions are seen in the Pollack Farm metatarsal, which we consider to be early Hemingfordian on other fau-



**Figure 4.** Chalicothere (A–G) and rhinoceros (H–O) of the Pollack Farm Local Fauna. A–G, cf. *Tylocephalonyx* sp.; A, USNM 475848, incomplete left M1 or M2; B, USNM 475843, left P3 or P4; C–D, USNM 475849, ungual phalanx in C, lateral, and D, dorsal views; E, USNM 475838, left third metatarsal; F–G, USNM 475850, left phalangeal duplex of digit II of manus, in F, anterior, and G, radial views. H–O, Rhinocerotidae; H, USNM 475923, right M3; I, USNM 475842, right P2; J, USNM 475837, left M1 or M2; K, USNM 475841, left P1; L, USNM 475839, right dp3; M, USNM 475840, right i2; N–O, USNM 475931, part of right mandible with dp2–3, in N, occlusal, and O, lateral views. All approximately X1. Scale in millimeters.

nal grounds.

The phalangeal duplex (USNM 475850, Fig. 4F–G) is much abraded but does retain some characters that suggest generic allocation. Its overall length is 80.6 mm. Its metacarpal facet is asymmetrical, with a small “ulnar tongue” (see Coombs, 1979:47, fig. 25A), it has some degree of what Coombs (1979) termed “crooked fusion” between proximal and medial phalanges, and its distal facet appears to be quite deeply grooved. These details are all characteristic of *Tylocephalonyx*, but in this specimen they all seem to be developed to a lesser degree than in the duplex of *T. skinneri* illustrated by Coombs (1979:47, fig. 25).

The ungual phalanges (USNM 475849, USNM 475935) are also highly abraded. USNM 475849 (Fig. 4C–D) shows the deep fissure so characteristic of chalicotheres; it is small, with no enlarged dorsal process, perhaps belonging to one of the pedal digits. USNM 475935 consists essentially of the proximal, articular end, but the strongly keeled articulation that continues into a long dorsal process almost certainly identifies it as from digit II of the manus. Neither of these phalanges has generically diagnostic characters.

The elements that do have generically useful characters, i.e., the upper molar, upper premolar, and the third metatarsal, are more consistent with *Tylocephalonyx* than with *Moropus*. There is some indication, especially from the metatarsal, that this Pollack Farm chalicothere is smaller than *T. skinneri*, or at least that it has shorter but more robust feet. Its early Hemingfordian age would make it older than any material previously referred to *Tylocephalonyx*, and it seems worth reiterating that the Pollack Farm metatarsal has characters otherwise present only in the oldest material previously identified as *Tylocephalonyx*, from the late Hemingfordian Split Rock fauna of Wyoming. We also note that Frailey (1979) reported a chalicothere, which he regarded as a small indeterminate species of *Moropus*, from the Arikareean of Florida (Buda Local Fauna); however, Frailey (1979:148) pointed out characters of the metatarsals in which “the Buda chalicothere is similar to an unnamed new genus of North American Schizotheriinae in which the metapodials are much more shortened and stocky.” The unnamed genus became *Tylocephalonyx* Coombs, 1979. Albright (1991) recently described a fauna (the Toledo Bend Local Fauna) from extreme eastern Texas that he considered Arikareean, and which includes a chalicothere. Albright (1991:127) assigned his chalicothere to *Moropus* “based on the morphology and physical dimensions of the Mt IV..., and on its similarity to *Moropus* sp. described by Frailey (1979)” from the Buda Local Fauna; Albright also noted that metatarsal characters considered by Coombs (1978) to be diagnostic of *Moropus* (the occurrence of an ectocuneiform facet on Mt IV) appear to be absent on both the Buda and Toledo Bend material. The weight of evidence, though not conclusive, seems strongly to suggest that the chalicothere *Tylocephalonyx* might have had a long history in the eastern and gulf coast regions of North America before it first appears in the classical late Hemingfordian of the Great Plains.

**Family RHINOCEROTIDAE Gray, 1825**  
**Unidentified Genera (Figure 4H–O)**

Material.—USNM 475837, right M1 or M2; USNM 475923, right M3; USNM 475842, right P2; USNM 475841,

left P1; USNM 475840, right tusk (lower second incisor); USNM 475931, cast of right dentary fragment with dp2 and dp3, and alveolus for dp1, in Virginia Museum of Natural History; USNM 475839, cast of right dp3 in private collection; USNM 475847, partial left astragalus.

Discussion.—It seems unlikely that this material can be confidently identified to genus, and perhaps equally unlikely that it all represents one taxon. Resemblances are seen to the smaller forms of both *Diceratherium* and *Menoceras*. Specimens representing young individuals of both genera were found in the collections of AMNH, and if these specimens are correctly referred, then the deciduous dentition in the Delaware material (USNM 475839 and 475931) seems to have closer resemblance to that of *Diceratherium* in some characteristics: dp2 is larger relative to dp3, and the alveolus for dp1 seen in USNM 475931 (Fig. 4N) indicates a relatively stouter dp1 than is present in material referred to *Menoceras*. This evidence is suggestive rather than indicative, however, and the Delaware material otherwise has characters that seem to indicate a rhino more progressive than *Diceratherium*. The P2 (USNM 475842, Fig. 4I) and the M3 (USNM 475923, Fig. 4H), for example, have distinct crochets. USNM 475837 (Fig. 4J), M1 or M2, is well worn, but shows the metaloph bulging anteriorly near the ectoloph, suggesting the base of a crochet, and the protoloph bulging posteriorly buccal to the protocone, suggesting an antecrochet. Also in this tooth, the protocone is well defined by posterior and anterior constrictions of the protoloph. H. E. Wood (1964) described *Menoceras barbouri* from the Thomas Farm of Florida as having the protocones only slightly pinched off in this way. In USNM 475837, the protocone is as distinct as it is in teleoceratine rhinoceroses, suggesting that this tooth might represent *Brachypotherium*. The Pollack Farm teeth are larger than those of *Menoceras barbouri*, and are just slightly smaller than those of the large aceratherine rhino *Floridaceras whitei* Wood, 1964, also from Thomas Farm.

Dimensions of the Pollack Farm rhino teeth are given

**Table 3**

Measurements in millimeters of teeth of Rhinocerotidae of the Pollack Farm Local Fauna. AP = anteroposterior, TR = transverse.

SPECIMEN	AP	TR
USNM 475841, dP1	24.3	22.6
USNM 475842, P2	30.5	34.7
USNM 475837, M1 or M2	46.0	51.6
USNM 475921, M3	37.1	42.6
USNM 475931, dp2	24.8	13.9
USNM 475931, dp3	30.2	16.3
USNM 475839, dp3	31.8	17.8
USNM 475840, I2	—	19.3

in Table 3.

**Order ARTIODACTYLA Owen, 1848**  
**Suborder SUIFORMS Jaekel, 1911**  
**Family TAYASSUIDAE Palmer, 1897**  
*Cynorca* Cope, 1867  
*Cynorca sociale* (Marsh, 1875)

Material.—USNM 475835, LC1, missing most of crown; USNM 475820, LP2; USNM 475821, LP3 in maxil-

lary fragment; USNM 475901, RP3; USNM 475893, RP4; USNM 475920, cast of LM1 in fragment of maxilla, from private collection; USNM 475892, part of RM1 with metacone, protocone, and metaconule; USNM 475932, cast of Lc1, missing much of crown, from private collection; anterior half of Rp2 in private collection; USNM 475823, Lm1; USNM 475922, cast of anterior half Rm1 in private collection; USNM 475822, Lm2; USNM 475921, cast of Lm3 in private collection; USNM 475919, cast of part of left mandibular ramus, edentulous, with alveoli for c1, p2, p3, p4, and part of m1; USNM 475878, fragment of right mandibular ramus, edentulous, with alveoli for p2, p3, and part of p4; USNM 475882, distal end right humerus; USNM 475806, proximal half right ulna; USNM 475827, right metacarpal III; USNM 475791, distal end left femur; USNM 475888, distal end right tibia; USNM 475871, right calcaneum, missing tuber calcis; USNM 475868, left astragalus; USNM 475875, right astragalus; USNM 475879, left astragalus; USNM 475890, left astragalus; USNM 475869, left navicular; USNM 475826, right metatarsal II; USNM 475800, proximal half left metatarsal II; USNM 475877, distal end metapodial; USNM 475885, medial phalanx; USNM 475874, medial phalanx.

Discussion.—This small peccary is among the most common of the land mammals comprising the Pollack Farm Local Fauna, suggesting that it was also among the more common of the land mammals in Delaware during Hemingfordian time. It is represented by teeth and miscellaneous postcranial elements (Fig. 5A–J). Most dental positions are represented, even though no single specimen has more than one tooth, and there is no association to suggest that any two teeth might have been derived from one individual. All of the teeth clearly represent a small species of *Cynorca*, and there is no evidence to suggest that more than one species of *Cynorca* is represented. The appropriate species name to be applied is less clear.

The upper canine is represented by only one specimen, which lacks most of the crown. The size of canines in peccaries is so variable (Wright and Eshelman, 1987:609), and primitively sexually dimorphic (Wright, 1993), that they are not diagnostic in any case.

The P2 and P3 differ in size, but are similar in that each consists predominantly of a large paracone buttressed posteriorly and posterobuccally by a broad posterior cingular shelf and anteriorly by a small but distinct anterior cingulum. The posterior cingulum has a very rugose occlusal surface on the unworn P3 (USNM 475901, Fig. 5C). Morphologically these teeth are closely comparable to those of *Cynorca proterva* (Wright and Eshelman, 1987: fig. 3), to those of “tayassuid species A” of Wright and Eshelman (1987: fig. 3), and also to those of specimens referred to *C. sociale* by Woodburne (1969: pl. 41, fig. 7). They are slightly larger than comparable teeth of *C. sociale* and “tayassuid species A,” and slightly smaller than those of *C. proterva*.

The Delaware P4 (USNM 475893, Fig. 5D) is like that of other *Cynorca* species in being more nearly molariform than the more anterior premolars. In most respects it is similar to the P4 of *C. proterva*, “tayassuid species A,” and *C. sociale*. It differs in having more definite separation of the paracone and metacone, and in this respect appears to be more nearly comparable to the P4 of *C. occidentale* (see Woodburne, 1969, pl. 43, fig. 3). In size, it is like P2 and P3

in being larger than that of *C. sociale* and “tayassuid species A,” and smaller than that of *C. proterva*.

The M1 (USNM 475920, Fig. 5E) does not differ from that of the other small species of *Cynorca*, except for its intermediate size, larger than that of *C. sociale* and “tayassuid species A,” and smaller than that of *C. proterva*. M2 and M3 are not represented in the Delaware sample; M2 alveoli preserved in USNM 475920 indicate that, as in other *Cynorca*, M2 is substantially larger than M1.

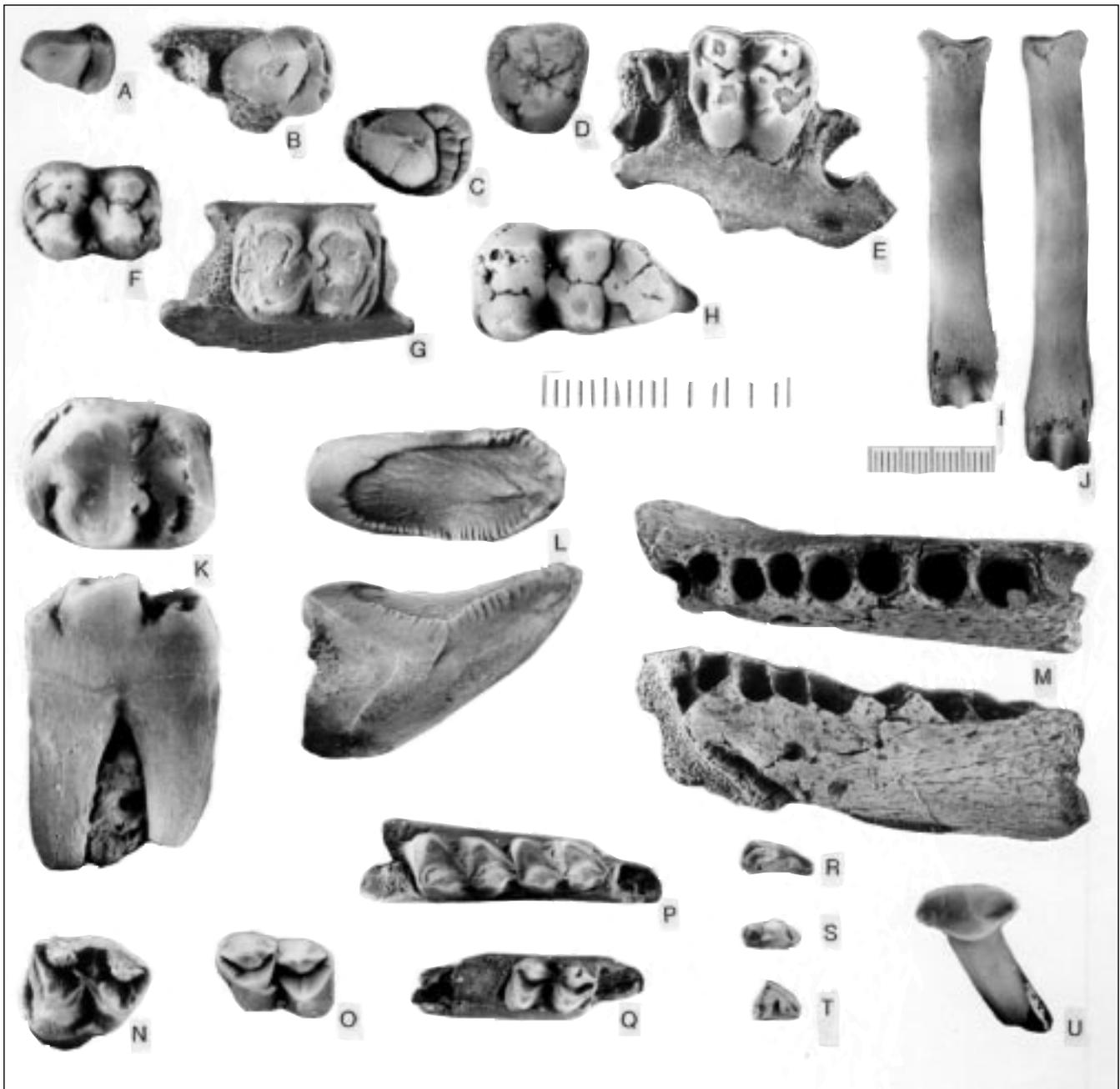
The lower canine is represented by USNM 475932, which lacks much of the crown and affords no useful information. Lower premolars are represented in the Pollack Farm sample only by the anterior half of p2 (specimen in private collection). Little can be said beyond noting that the main cusp, the protoconid, is very tall and is buttressed anteriorly by a low accessory cusp (paraconid?). Wright and Eshelman (1987:607) mention that in “tayassuid species A” and in *C. proterva* the protoconid is tall and steep-sided, more so in the former than in the latter. Wright and Eshelman (1987:606) also note that their “tayassuid species A” compares most favorably with specimens of *C. sociale*, especially in having steep-sided protoconids on p2 and p3. In the Delaware p2, the protoconid appears to have been even taller and more nearly cylindrical than in the other species mentioned. Each of the lower molars is represented in the Delaware sample. Morphologically, nothing distinguishes them from the corresponding teeth of other small *Cynorca*.

Measurements suggest that the lower molars were not only larger than those of “tayassuid species A” and *C. sociale*, but perhaps also larger than those of *C. proterva*, although the small sample size ( $N = 1$  for each tooth) renders the comparison virtually meaningless. It does seem worth noting that the m3 is relatively larger even than in the other species. Woodburne (1969) pointed out that M3/m3 are reduced in size in later species of *Cynorca*, especially in the Barstovian species *C. occidentale*. Using measurements in the tables provided by Woodburne (1969) and Wright and Eshelman (1987), the ratio of m2 length/m3 length is 0.71 in “tayassuid species A,” 0.83–0.86 in *C. sociale*, 0.82–0.84 in *C. proterva*, and 0.82–0.94 in *C. occidentale*. This ratio in the Delaware sample is 0.75 (calculated from measurements of two teeth probably not of the same individual), a value intermediate between “tayassuid species A” one hand and *C. sociale* and *C. proterva* on the other.

Wright and Eshelman (1987) noted the similarities between their “tayassuid species A” from bed 2 of the Calvert Formation at Popes Creek, Maryland, and specimens that Woodburne (1969) had referred to *C. sociale* from the early Miocene John Day Formation of Oregon, but they did not refer the Maryland material to *C. sociale*. The Delaware material also seems to share the greatest similarity with *C. sociale* and “tayassuid species A.” The differences in size (if real—the sample sizes are so small that the differences may not be significant) seem sufficiently slight to be explained as individual variation or as differences in geographically distant populations. And there seems to be no other justification for not assigning the Delaware material to *Cynorca sociale*. “Tayassuid species A” of Wright and Eshelman (1987) could probably be assigned to the species with the same justification.

#### ***Hesperhys* Douglass, 1903 or *Desmathyus* Matthew, 1907**

Material.—USNM 475819; right p4; USNM 475813, right i3.



**Figure 5.** Artiodactyls of Pollack Farm Local Fauna. A–J, *Cynorca sociale*; A, USNM 475820, left P2; B, USNM 475821, left P3; C, USNM 475901, right P3; D, USNM 475893, right P4; E, USNM 475920, maxilla fragment with left M1; F, USNM 475823, left m1; G, USNM 475822, mandibular fragment with left m2; H, USNM 475921, left m3; I, USNM 475827, right third metacarpal; J, USNM 475826, right second metatarsal. K–L, *Desmathyus* or *Hesperhys*; K, USNM 475819, right p4 in occlusal (above) and lingual (below) view; L, USNM 475813, right i3, in occlusal (above) and lateral (below) view. M, USNM 475825, leptachenine oreodont, edentulous fragment of left dentary, in occlusal (above) and lateral (below) view. N–O, *Blastomeryx galushai*; N, USNM 475912, part of left M3; O, USNM 475873, left m1 or m2. P–T, Ruminantia, genus uncertain; P, USNM 475824, fragment of left dentary with m1–m2; Q, USNM 475828, fragment of right dentary with m1 or m2; R, USNM 475865, left p3 or p4; S, USNM 475866, right p2 or p3; T, USNM 475864, part of left premolar, probably p4. U, ?Anthracotheriidae, USNM 475803, ?right i1. All approximately X2 except I, J, which are approximately X1. Scale bars in millimeters.

Discussion.—This material (Fig. 5K–L) represents a much larger peccary than that discussed above. The p4 talonid is broad, but has a single central anteroposteriorly directed crest that forms the highest part of the talonid, as is seen in *Desmathyus* and *Hesperhys*; the talonid of p4 in *Cynorca*, by contrast, has both entoconid and hypoconid. Close general resemblance was found with several specimens in the Frick Collection (AMNH) identified as *Desmathyus* and *Hesperhys*; the closest match was with the right p4 in a very large peccary, labeled *Hesperhys*, in the Frick Collection (AMNH) from Humbug Quarry in the Sheep Creek Formation of western Nebraska (the specimen is uncataloged but has “Sioux County” field number 259-16237).

#### ?Family ANTHRACOTHERIIDAE Leidy, 1869

Material.—USNM 475803, incisor, possibly right i1.

Discussion.—This incisor (Fig. 5U) has a long root and a broadly expanded crown that is blunt rather than spatulate. Although definitive identification is probably not possible, it is certainly not an incisor of any taxon that is otherwise represented by teeth in this assemblage. It could conceivably represent Tylopoda, perhaps a protoceratid or camelid, but its closest morphological comparisons seem to be with anthracotheres. In the absence of any other anthracothere material in the Pollack Farm assemblage, this identification must be considered provisional. The tooth is of appropriate size to be the lower first incisor; where known, i1 of anthracotheres is substantially smaller than i2 and i3 (for example, in *Elomeryx*, see Macdonald, 1956, fig. 5). The latest occurrence of anthracotheres in North America is the early Hemingfordian *Arretotherium fricki* (Macdonald and Schultz, 1965; Macdonald and Martin, 1987), from the Runningwater Formation of northwestern Nebraska, and from the Flint Hill fauna of South Dakota. Lower incisors of *A. fricki* are not known. Albright (1991) referred some teeth, including incisors, from the late Arikareean of eastern Texas to *A. acridens*, a species also known from classical late Arikareean localities of Nebraska, South Dakota and Montana.

#### Family OREODONTIDAE Leidy, 1869

##### ?Subfamily

Material.—USNM 475825 (Fig. 5M), an edentulous fragment of left dentary with alveoli from posterior edge of the caniniform p1 to anterior edge of m2.

Discussion.—A small oreodont is represented by this single specimen. Enough of the jaw is preserved to show the large symphysis, deep alveolus for a large, caniniform p1, and absence of premolar diastemata, characters common to all oreodonts. In its small size and apparent crowding of premolars indicated by alveoli, the specimen is comparable to leptaucheniines such as *Cyclopidius*; its size, for example is close to that of *C. simus*. However, leptaucheniines are not otherwise known later than the end of the Arikareean, suggesting that this specimen instead might represent a small merychiine such as *Merychius minimus* or *M. crabilli*. Based on alveoli, we estimate the length of p1–p4 of the Delaware specimen at about 25 mm, which is smaller than any comparable measurement given for species of *Merychius* by Schultz and Falkenbach (1947, table 1). In the

absence of teeth, confident identification to genus is out of the question.

#### Suborder RUMINANTIA Scopoli, 1777

#### Family MOSCHIDAE Gray, 1821

#### *Blastomeryx* Cope, 1877

#### *Blastomeryx* (*Parablastomeryx*) *galushai* Frick, 1937

Material.—USNM 475912, cast of part of left M3 in private collection; USNM 475873, left m1 or m2.

Discussion.—The relatively small size of the metaconule of the upper molar (Fig. 5N) identifies it as an M3. So far as comparisons can be made it is identical to M3 of the holotype of *Blastomeryx* (*P.*) *galushai* (F:AM 33775), from the Runningwater Formation in Dawes County of Western Nebraska (Frick, 1937, fig. 22A). The similarity extends even to the presence of small bifurcations at the posterobuccal end of the protocone and the anterobuccal end of the metaconule. The maximum anteroposterior measurement of USNM 475912 is 10.2 mm; the comparable measurement of the type (F:AM 33775) is 9.9 mm. The lower molar (USNM 475873, Fig. 5O) has a distinct *Paleomeryx* fold, one of the characteristics of *Blastomeryx*, and is of appropriate size to be assigned to the same species; it measures 9.1 mm AP and 6.2 mm TR. These measurements indicate a substantially smaller animal than *Blastomeryx* (*Parablastomeryx*) *floridanus* (White, 1940; Maglio, 1966) of the Thomas Farm Local Fauna of Florida.

#### Families Uncertain

#### Genera and Species Unidentified

Material.—USNM 475824, left dentary fragment with m1–m2; USNM 475828, right dentary fragment with m1 or m2; USNM 475894, incomplete right P3; USNM 475865, left p3 or p4; USNM 475866, right p2; USNM 475864, incomplete left premolar, probably p4.

Discussion.—This material is all of approximately the right size to represent one species of small ruminant, but differences in premolars suggest that more than one species is represented. Unfortunately, important characters such as the length of the diastema and spacing of premolars are not preserved. The molar in USNM 475828 clearly lacks a *Paleomeryx* fold, has a small accessory cuspid between the bases of protoconid and hypoconid, and the anterior arm of its hypoconid fuses with the posterior arm of the protoconid and with the entoloph. In USNM 475824, which is similar in size and seems superficially similar, each of the molars, though badly worn, clearly had a *Paleomeryx* fold, each had accessory cuspids between bases of hypoconid and protoconid, and in each the anterior arm of the hypoconid is free. These differences suggest that the two specimens represent different taxa. The one molar in USNM 475828, possibly m1 though most likely m2, measures 7.3 mm AP and 4.7 mm TR. In USNM 475824, the m1 is 7.4 mm AP, 4.6 mm TR, and m2 is 8.3 mm AP, 5.9 mm TR.

Being preserved as isolated teeth, the premolars offer little aid to identification. The upper premolar, probably P3, USNM 475894, is incomplete posteriorly and well worn, but clearly had a distinct cusplike parastyle ahead of the large paracone, and a distinct protocone directly lingual to the paracone. USNM 475865, possibly p3 but most likely p4 (Fig. 5R), is sufficiently worn that the distinct paraconid has

a triangular outline, suggesting that it may have been bifurcate when unworn; a prominent metaconid wing extends posterolingually from the protocone, and the posterior hypoconid crest turns lingually to end at the posterolingual corner of the tooth in a slightly expanded entoconid; it is 5.6 mm AP and 2.6 mm TR. USNM 475866 is a simpler tooth, most likely p3 but possibly p2 (Fig. 5S); its bladelike paraconid is set obliquely to the anterior protoconid crest, the metaconid crest is but a rib at the posterolingual corner of the protoconid, and the hypoconid crest has a posterolingually directed spur midway between protoconid and the heel of the tooth. USNM 475864 is the anterior half of a tooth (Fig. 5T), almost certainly p4. It is somewhat worn, but clearly had a prominent paraconid that was bifurcate, and a distinct, cusp-like expansion of the metaconid.

The premolars with bifurcate paraconids, in some instances combined with a prominent metaconid, and the molars with *Paleomeryx* folds and free anterior wings of hypoconid, are more likely referable to a small species of blastomerycine moschid. They are too large to represent *Machaeromeryx gilchristensis* (White, 1941; Maglio 1966), the smaller blastomerycine from the Thomas Farm Local Fauna of Florida. The simpler premolar (USNM 475866) and the molar (USNM 475828) that lacks the *Paleomeryx* fold and has the anterior arm of the hypoconid fused to the posterior arm of the protoconid are more reminiscent of Leptomerycidae.

The nature of this material probably renders impossible its reference to genera, though the weight of evidence does suggest that two species of small ruminant are present, and that each may represent a different family.

#### AGE OF THE POLLACK FARM LOCAL FAUNA

Certain taxa within the Pollack Farm Local Fauna serve to constrain the age rather precisely within the North American Land Mammal Age system. *Amphicyon* and *Plesiosorex*, for example, are immigrant taxa whose first appearances in North America, about 20 million years ago, define the beginning of Hemingfordian time (Tedford et al., 1987). The fauna also includes the amphicyonid carnivore *Cynelos* which is among the taxa whose latest occurrence is in the early Hemingfordian (Tedford et al., 1987). The co-occurrence of these taxa restricts the age to early Hemingfordian, and other elements of the fauna are consistent with this date. The closest comparisons for some of the teeth from the Pollack Farm Site are with specimens from the Runningwater Formation of western Nebraska, its correlative in South Dakota (Flint Hill Local Fauna), with Quarry A Local Fauna of northeastern Colorado, and with the Thomas Farm Local Fauna of Florida. These are the well known, diverse faunas that typify the early Hemingfordian (Tedford et al., 1987).

Strontium-isotope age estimates on mollusk shells from the Pollack Farm Site range from 17.8 ma to 18.2 Ma with a mean of  $17.9 \pm 0.5$  Ma (Jones et al., 1998). These dates are in very close agreement with radiometric dates established for late early Hemingfordian faunas of the western states (Tedford et al., 1987, fig. 6.2).

#### MARINE TO NONMARINE CORRELATIONS

The land mammals that constitute the Pollack Farm Local Fauna occur in coarse shelly intervals within the

Cheswold sands of the Miocene Calvert Formation (Benson, 1993, 1998). This shelly sand is dominated by disarticulated shells of bivalves, but also has abundant gastropods, together amounting to more than 100 species of mollusks (Ramsey, et al., 1992; Ward, 1998). Crustaceans and other invertebrates are also represented, but are much less common. Ward (1998, fig. 3) assigns the Pollack Farm mollusks to the lower part of his M13 Interval Zone, which he designates M13-A, of Burdigalian age, consistent with the Hemingfordian age determined by the land mammal assemblage. In addition to the terrestrial mammals discussed above, the associated vertebrates include numerous kinds of sharks and bony fish, amphibians (salamander), reptiles (crocodilians, turtles, lizards), and marine mammals (cetaceans, sirenian, and a pinniped); these are discussed in other chapters of the present volume.

Benson (1993, 1998) assigns radiolarians from sandy silts between the lower and upper shelly sands at the Pollack Farm Site to the *Stichocorys wolffii* Zone, a global marine, early Miocene biozone as defined regionally in the middle Atlantic Coastal Plain by Palmer (1986). Benson (1998) estimates its age as between 17.3 and 19.2 Ma and postulates, on the basis of information from boreholes and other stratigraphic data, that the Pollack Farm Site is in the upper part of the *S. wolffii* Zone, and, therefore, closer to 17.3 than to 19.2 Ma. Benson (1993, 1998) also identified the diatom *Actinoptychus heliopelta* from the radiolarian-bearing silts; the total range of this species (most of the early Miocene) defines East Coast Diatom Zone (ECDZ) 1 of Andrews (1988).

Radiolarian and diatom biostratigraphy and stratigraphic correlation of outcrops and borehole geophysical logs led Benson (1993, 1998) to conclude that the Shiloh marl of nearby New Jersey, the source of the Shiloh Local Fauna which consists of the single land vertebrate *Tapirus validus* described by Marsh (1871), is older than the fossiliferous beds exposed at the Pollack Farm Site. Benson (1998, fig. 5) shows that sands stratigraphically equivalent to the Shiloh marl underlie the lowermost beds excavated at the Pollack Farm Site and that the entire section exposed at the latter site is missing updip in Delaware and at the Shiloh, New Jersey, site by having been eroded. Sugarman et al. (1993) gave strontium-isotope age estimates of 20.0 to 20.3 Ma for the Shiloh marl, which Benson (1977) suggests is evidence for an unconformity between the Shiloh-equivalent beds and the ~18-Ma fossil-bearing beds at the Pollack Farm Site.

Farther to the northeast in coastal New Jersey, a small assemblage of land mammals, the Farmingdale Local Fauna (Tedford and Hunter, 1984), occurs in the basal Kirkwood Formation. Benson (1993, 1998) concluded on the basis of its stratigraphic position that the Farmingdale Local Fauna is older than the Shiloh Local Fauna. These correlations are consistent with the terrestrial mammal data; the single specimen of *Tapirus validus* that constitutes the Shiloh Local Fauna is not age-diagnostic, but better information is afforded by the assemblage called Farmingdale Fauna, which includes (Tedford and Hunter, 1984) a horse, *Anchitherium* sp., the rhinos *Diceratherium matutinum* and *Menoceras* cf. *M. cooki*, the entelodont *Daedon (Ammodon) leidyannum*, the peccary *Hesperhys antiquus*, and the protoceratid *Prosynthetoceras* sp. Tedford and Hunter (1984) considered

the Farmingdale Fauna early Hemingfordian, noting that its constituent genera are known to coexist in early Hemingfordian time at other sites in the western United States. However, these genera also coexist in Arikareean time, and some taxa, the large entelodont for example, are more characteristic of late Arikareean time. We note also that Tedford et al. (1987:185) list *Diceratherium* among the taxa whose latest occurrences are in the late Arikareean. A late Arikareean, rather than Hemingfordian, assignment for the Farmingdale fauna is also in better agreement with the strontium-isotope age estimates of 19.2 to 22.6 Ma  $\pm$  0.5 m.y. for the lower Kirkwood Formation (Sugarman et al., 1993). Benson's (1998, fig. 6) summary of the age estimates derived from analysis of the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios published by Sugarman et al. (1993) for the basal Kirkwood in the Berkeley and Lacey wells, those closest to the Farmingdale Site, shows a late Arikareean age for the Farmingdale Fauna.

From the Calvert Cliffs, along the western side of Chesapeake Bay in Maryland, a terrestrial mammalian assemblage occurs in the upper part ("Zones" 13–15) of the Calvert Formation and the basal part of the overlying Choptank Formation (Gazin and Collins, 1950; Tedford and Hunter, 1984). This fauna is substantially younger than the Pollack Farm assemblage. Tedford and Hunter (1984) concluded that the one land mammal that occurs slightly lower ("Zone" 10) in this sequence, "*Tomarctus*" *marylandica*, is consistent with an early Barstovian age assignment. The other land mammals, however, seem to be an essentially coeval assemblage representing later Barstovian time; presence of the proboscidean *Gomphotherium* is critical to this correlation, as the first appearance of proboscideans in North America is used to define the later part of the Barstovian Land Mammal Age (Tedford et al., 1987). Principally on the basis of the peccaries present, Wright and Eshelman (1987) considered bed 10 to be late Hemingfordian or early Barstovian, bed 14 to be early late Barstovian, and bed 17 to be late Barstovian. Correlations to microfossil biozones indicate bed 10 is of early Barstovian age (Benson, 1998, fig. 6).

To the west of Chesapeake Bay, the basal Calvert Formation crops out along the lower Potomac River. The peccary fossils discovered there, at the locality termed Popes Creek, were those called "tayassuid sp. A" by Wright and Eshelman (1987) and considered to be latest Arikareean or early Hemingfordian. These peccaries compare closely with the smaller peccary from the Pollack Farm Site that is referred herein to *Cynorca sociale*. This suggests a close temporal correlation between the lower Calvert Formation at the Pollack Farm Site in Delaware and the basal Calvert along the lower Potomac River. Benson (1998, fig.6) shows two different interpretations for correlation of the Popes Creek beds—early Hemingfordian on the basis of dinoflagellates or late Hemingfordian on the basis of radiolarians.

The Pollack Farm Local Fauna shares its greatest homotaxial similarity with the Thomas Farm Fauna of northern Florida. The Thomas Farm assemblage occurs in a sinkhole filling, isolated from a stratigraphic sequence that would link it directly to other chronologies; however, the land mammals of the Seaboard Local Fauna (Olsen, 1964) from the lower Torreya Formation, also in northern Florida, seem to be virtually identical to those from Thomas Farm (Tedford and Hunter, 1984), and do occur in a stratigraphic context that affords dating and correlation. According to Banks and Hunter

(1973), the invertebrate fauna from the Seaboard locality correlates with planktonic foraminiferal zones upper N5 and N6 of Blow (1969). Bryant et al. (1992) provided a strontium-isotope age estimate of  $18.4 \pm 1.0$  Ma on a mollusk sample from the Seaboard locality; this age is consistent with the invertebrate and vertebrate biochronologies.

To summarize, the Pollack Farm Local Fauna is approximately 18 million years old, and referable to the early Hemingfordian; its stratigraphic context and direct faunal associations indicate correlation with the *Stichocorys wolffii* Radiolarian Zone, as defined by Palmer (1986) for the Miocene of the middle Atlantic coastal Plain, and with East Coast Diatom Zone 1 (Andrews, 1988). The abundant associated molluscan fauna (Ward, 1998) is of Burdigalian age, consistent with the early Hemingfordian age of the land mammals. Less direct but nevertheless confident correlations are with Planktonic Foraminiferal Zone upper N5 or N6, and with the later Burdigalian and late early Miocene of Europe.

### PALEOENVIRONMENTAL SETTING

The deposits from which the terrestrial mammalian fossils were recovered are shallow marine sediments. The land mammal assemblage suggests a nearby forested habitat, probably with some open grassy areas, and fresh water. A possible Holocene analog might be one of the larger Virginia coastal barrier islands such as Cedar or Parramore Islands, which have forests, freshwater ponds, and some open park-like grasslands. Beaver, peccaries, and browsing and grazing horses could all find suitable habitat there. In fact, horses have been successfully introduced to barrier islands such as Assateague, in Virginia and Maryland, and Bogue Banks in North Carolina.

The chalicotheres and rhinos could also find suitable habitat on such islands, but these remains could also be transported as carcasses washed to sea by flooded rivers; however, Cutler (1998) concludes from his taphonomic studies that carcass rafting of the Pollack Farm vertebrate remains is unlikely. Gibson (1971, 1983) postulates that the northern part of Delaware during early to middle Miocene time was predominantly deltaic. This would help explain the diversity of habitats suggested by the terrestrial mammals as well as by the other vertebrates reported in this volume. Plant microfossils and dinocysts suggested to Groot (1992), and radiolarians and foraminifers suggested to Benson et al. (1985), that during the early Miocene this part of Delaware was covered by a relatively shallow marginal marine to inner neritic sea with broad coastal wetlands.

Thus a second and possibly more compelling modern analog would be a delta with flowing fresh-water rivers and streams, oxbow lakes and ponds, with marshes and swamps developed in the lowlands and forest and open park-like grasslands on the higher elevations.

The abundance of terrestrial mammal remains at the Pollack Farm Site is remarkable in comparison to other Atlantic Coastal Plain deposits such as the Lee Creek Mine, North Carolina, and the Calvert Cliffs of Maryland's Chesapeake Bay western shore, where terrestrial mammalian fossils are also found. The Pollack Farm Site was a temporary borrow pit of less than one-half square mile, available for collecting for about one year, and produced a minimum of 204 identifiable specimens of land mammals, representing a minimum of 26 species. In contrast, the Lee Creek Mine

began operation in 1964 and mined an average of 75 acres per year (McLellan, 1983); in more recent years the rate of mining has increased and the mined area is now several miles square. Collecting at Lee Creek began at least by 1967 (Ray, 1983) and continues to the present. The terrestrial mammal assemblage consists of approximately 143 identifiable bones and teeth, representing about 20 species.

Calvert Cliffs are a series of wave-cut bluffs up to 130 feet high that extend about 25 miles along the western shore of Chesapeake Bay (Vogt and Eshelman, 1987). Terrestrial mammalian fossils from the Chesapeake Group, including the Calvert Formation, of the Calvert Cliffs, consist of about 17 taxa represented by approximately 167 identifiable bones and teeth. Fossil vertebrates have been collected from these cliffs since at least 1818 and have been studied by scientists since at least 1842. The Smithsonian Institution has maintained a program of collecting at Calvert Cliffs since at least 1907, and amateurs have scoured the cliffs since the 1960s.

It is clear that the lower shell bed at the Pollack Farm Site represents an environment that was much more favorable for preservation of land mammal remains than were the other sites known in the middle Atlantic Coastal Plain.

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