Barstovian (middle Miocene) Land Mammals from the Carmel Church Quarry, Caroline County, Virginia

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ABSTRACT

Excavation of marine sediments of the Calvert Formation at the Carmel Church Quarry has resulted in the collection of remains of several land mammals. These include the first reports from the upper Calvert Formation of the family Dromomerycidae and of the equid *Calippus* cf. *regulus* as well as the tayassuid “Prosthennops” *xiphidonticus* and a tapirid. The presence of *Calippus* cf. *regulus* and “Prosthennops” *xiphidonticus* indicate a late Barstovian age for this deposit, which is consistent with previous assessments based on diatoms.

Keywords: Miocene, Calvert Formation

INTRODUCTION

The middle Miocene Calvert Formation is extensively exposed in erosional cliffs along the Chesapeake Bay and various rivers in the Coastal Plain of Virginia and Maryland. While best known for its extensive marine fauna, the Calvert Formation has also produced significant remains of fossil land mammals. Cope (1868) first published a report of a land mammal (a peccary tooth) from the Calvert (see Woodburne, 1969, Wright & Eshelman, 1987, and Dooley, 2003 for discussion of this specimen). Further reports and summaries of Calvert land mammals include Gazin & Collins (1950), Woodburne (1969), Whitmore, (1971, 1984), Tedford & Hunter (1984), and Wright & Eshelman (1987). However, the number of published studies on Calvert land mammals belies the relative rarity of specimens. Only the Pollack Farm site in Delaware has produced large numbers of land mammals (Emry & Eshelman, 1998). The Pollack Farm specimens all come from the lower Calvert Formation (some authors assign these deposits to the equivalent Kirkwood Formation—see Ward, 1998). In contrast, the upper part of the Calvert Formation has produced only a few dozen land mammal specimens in approximately 150 years of collecting.
Jeffersoniana

The exposed Tertiary section of the Carmel Church Quarry in Caroline County, Virginia includes one bed of Calvert Formation sediments, approximately 0.5-1.0 meters thick (Dooley et al, 2004). Carmel Church has produced abundant remains of marine vertebrates including cetaceans, sirenians, phocids, marine reptiles, chondrichthians, and osteichthians (Dooley & Fraser, 2005). Carmel Church is the westernmost known exposure of the Calvert Formation, and is therefore possibly the nearest to the paleoshoreline as well. This may account for the unusual abundance of terrestrial mammals and plants relative to other localities in the upper part of the Calvert Formation.

METHODS

The Carmel Church specimens were compared with published illustrations of comparable specimens, as well as specimens from other localities stored at the Florida Museum of Natural History, the American Museum of Natural History, and the United States National Museum. Anatomical terminology and measurements for equids follows Hulbert (1988); for tayassuids, Wright & Eshelman (1987). North American land mammal biostratigraphy follows Carrasco et al., 2005.

Anatomical abbreviations: c, canine; d, deciduous tooth; I, incisor; m, molar; p, premolar. Upper teeth are designated by uppercase abbreviations, lower teeth by lowercase abbreviations.


SYSTEMATIC PALEONTOLOGY
Order PERISSODACTYLA Owen, 1848
Family EQUIDAE Gray, 1821
Genus CALIPPUS Matthew & Stirton, 1930
Calippus cf. regulus Johnston, 1937

Referred specimen: VMNH 3529, partial maxillae with portions of ten teeth, including R DP3-4, R M1-2, L DP2-4, L M1-2, and non-erupted R P3. Collected by Brett Dooley, July 2001 (Figure 1).

This specimen was originally reported as Merychippus sp. (Dooley & Fraser, 2005). It includes maxillary fragments with ten preserved teeth, including worn deciduous premolars, slightly worn first molars, and unworn, non-erupted or partially erupted second molars. The partial non-erupted right P3 is in situ above DP3. In the
deciduous premolars, the elongate protocone is connected to the protoselene. The fossettes are simple, and there is no pli caballin. The hypoconal groove is open in DP2 and forms a lake in DP3. The parastyle and mesostyle are fairly prominent. The fossettes are simple, with a single small pli postfossette in DP4.

Tooth eruption patterns indicate that VMNH 3529 was a young juvenile. In *Equus*, the first permanent tooth to erupt is M1, at an age of approximately one year. In VMNH 3529, M1 exhibits only very slight wear, while M2 was unworn and had probably not erupted, and M3 had not begun to form.

The Carmel Church specimen is very similar in both size and overall morphology to *Calippus regulus* and *Calippus proplacidus*. Compared to *C. proplacidus*, *C. regulus* has molar crowns that are shorter anteroposteriorly but higher, and with simpler fossettes. Overall, VMNH 3529 is more similar to specimens referred to *C. regulus*. The DP enamel pattern of VMNH 3529 is similar to that of TMM 30896-173 (*C. regulus*) as figured by Quinn (1955); these specimens appear to represent comparable stages of growth and wear. Differences include the presence of a hypoconal lake in DP2-3 of TMM 30896-173, but in DP4 of VMNH 3529. The deciduous upper premolars of FAM 118206, also referred to *C. regulus*, lack hypoconal lakes. The crown length of M1 (approximately 16 mm) is a little larger than typical for *C. regulus*, and more typical for *C. proplacidus*, based on the data from Hulbert (1988). However, this length does fall within the range of preserved *C. regulus* specimens (for example, USNM 42431, AMNH 118230). The M1 crown height of VMNH 3529 falls within the range for *C. regulus*, and is greater than for *Calippus proplacidus* (Hulbert, 1988).

*Calippus regulus* has been reported from the late Barstovian to middle Clarendonian of the Great Plains and Texas Gulf Coast (Hulbert, 1988; Forsten, 1975; Quinn, 1955). *Calippus proplacidus* has been reported from the late Barstovian of Colorado, Nebraska, Texas, and Florida (Hulbert, 1988).

**Table 1. Measurements of teeth of VMNH 3529.**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteroposterior length of left DP3</td>
<td>18.5 mm</td>
</tr>
<tr>
<td>Anteroposterior length of right DP3</td>
<td>18.4 mm</td>
</tr>
<tr>
<td>Anteroposterior length of left DP4</td>
<td>19.1 mm</td>
</tr>
<tr>
<td>Anteroposterior length of right DP4</td>
<td>18.5 mm</td>
</tr>
<tr>
<td>Anteroposterior length of left M1</td>
<td>16.0 mm</td>
</tr>
<tr>
<td>Unworn crown height of left M1</td>
<td>45.2 mm</td>
</tr>
<tr>
<td>Anteroposterior length of right M1</td>
<td>16.4 mm</td>
</tr>
<tr>
<td>Unworn crown height of right M1</td>
<td>44.1 mm</td>
</tr>
<tr>
<td>Anteroposterior length of left M2</td>
<td>16.0 mm</td>
</tr>
</tbody>
</table>
Figure 1. VMNH 3529, *Calippus* cf. *regulus*, partial maxillae with teeth, occlusal view. Anterior is to the left. Scale = 5 cm.

Family EQUIDAE Gray, 1821
Genus indeterminate

Referred specimen: VMNH 1802, isolated right third metatarsal. Collected by Bryce Harrison, July 2003 (Figure 2).

VMNH 1802 is a nearly complete equid right metatarsal III. This specimen is smaller than FAM 69511, a referred specimen of *Merychippus coloradense*, but is considerably longer and more gracile than an uncatalogued metatarsal in the FAM collection, which is associated with material referred to *Calippus regulus*. The length of the FAM specimen is only 84% that of VMNH 1802, but the width at the distal end is 109% of VMNH 1802. The proximal articular surface in VMNH 1802 is flatter than in the FAM specimen. The different proportions and shape of this metatarsal compared to the FAM specimen suggests the possibility of a second genus of equid at Carmel Church.
Figure 2. VMNH 1802, Equidae, right metatarsal. A. anterior, B. posterior, C. medial, D. lateral. Scale = 5 cm.
TABLE 2. MEASUREMENTS OF EQUID RIGHT METATARSAL, VMNH 1802.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>165 mm</td>
</tr>
<tr>
<td>Width at proximal end</td>
<td>23 mm</td>
</tr>
<tr>
<td>Length at proximal end</td>
<td>20 mm</td>
</tr>
<tr>
<td>Width at distal end</td>
<td>19 mm</td>
</tr>
<tr>
<td>Length at distal end</td>
<td>15 mm</td>
</tr>
</tbody>
</table>

Family TAPIRIDAE Gray, 1821
Genus indeterminate

Referred specimens: VMNH 1803, partial right deciduous lower premolar. Collected by L. W. Ward, November 1991 (Figure 3). VMNH 1804, left third metacarpal. Collected by C. R. Harrison, March 2001 (Figure 4).

The tooth fragment is the posterior cusp of a deciduous lower left premolar. This fragment is smaller than the permanent premolars and molars in *Tapirus johnsoni* (FAM 37302). Compared to FAM 37302, the Carmel Church specimen has a more squared-off profile in occlusal view. The broken edge of the anterior cusp suggests that this cusp was narrower than in FAM 37302.

The left third metacarpal is similar in shape to the same element from *Tapirus webbi* (UF 26474). The Carmel Church specimen is smaller than *T. webbi*, with a metatarsal length about 85% of that in UF 26474.

TABLE 3. MEASUREMENTS OF TAPIRID PREMOLAR, VMNH 1803, AND LEFT THIRD METACARPAL, VMNH 1804.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of crown VMNH 1803</td>
<td>15 mm</td>
</tr>
<tr>
<td>Width of crown VMNH 1803</td>
<td>16 mm</td>
</tr>
<tr>
<td>Length VMNH 1804</td>
<td>119 mm</td>
</tr>
<tr>
<td>Width at proximal end VMNH 1804</td>
<td>26.5 mm</td>
</tr>
<tr>
<td>Length at proximal end VMNH 1804</td>
<td>22 mm</td>
</tr>
<tr>
<td>Width at distal end VMNH 1804</td>
<td>27 mm</td>
</tr>
<tr>
<td>Length at distal end VMNH 1804</td>
<td>21 mm</td>
</tr>
</tbody>
</table>
Figure 3. VMNH 1803, Tapiridae, right deciduous lower premolar. A. lateral, B. occlusal. Anterior is to the right. Scale = 1 cm.

Figure 4. VMNH 1804, Tapiridae, left third metacarpal. A. anterior, B. medial, C. lateral, D. posterior. Scale = 5 cm.
Order ARTIODACTYLA Owen, 1848  
Family TAYASSUIDAE Palmer, 1897  
Genus “PROSTHENNOPS” Wright & Eshelman, 1987  
“Prosthennops” xiphidonticus (Barbour, 1925)

Referred specimens: VMNH 1800, partial mandible including partial left and right canines, right p3, partial right m3, and left p3-m1. Collected by S. Whitehurst, November 2002 (Figure 5A-D). Tentative referrals: VMNH 1805, left second metatarsal. Collected by A. C. Dooley, Jr. and P. R. Murdoch, March 2004 (Figure 5E-H). VMNH1806, upper right canine. Collected by J. Sarao, June 2005 (Figure 5I-J).

The partial mandible includes portions of both dentaries with both canines, rp3, a portion of rm3, and lp3-m1 in situ. Root fragments of l1-l2 and r1 are also present.

The morphology of p3 matches closely p3 of USNM 25795, a specimen of “Prosthennops” xiphidonticus from the Calvert Formation in Westmoreland County, Virginia (Wright & Eshelman, 1987), although VMNH 1800 shows more wear than the Westmoreland specimen. In its lack of a distinct metaconid, VMNH 1800 is similar to “P.” xiphidonticus and distinct from the slightly younger “P.” niobrarensis (Wright, 1998), which is known from the Choptank Formation (Wright & Eshelman, 1987).

In USNM 20518, a specimen of “P.” xiphidonticus from Calvert County, Maryland, the metaconid of p4 has a posterolabial process (Wright & Eshelman, 1987); this process is also present in p4 of VMNH 1800, and also occurs in “P.” niobrarensis (Wright & Eshelman, 1987). Interestingly, in both VMNH 1800 and USNM 20518, m1 seems to show more extensive wear than the other lower teeth.

Only the base of the right canine is preserved. The complete but poorly preserved left canine shows evidence of wear both apically and along the posterior margin.

In spite of its adult dentition, VMNH 1800 is slightly smaller than either USNM 25795 or USNM 20518 (p3 crown length of 10.8 mm vs. 11.3 mm), and considerably smaller than “P.” niobrarensis specimens from the Choptank Formation (such as USNM 243740 with a p3 crown length of 13.5 mm). During the Miocene, the trend in peccaries is toward larger size (Wright & Eshelman, 1987).
Table 4. Measurements of teeth of VMNH 1800. All measurements in mm.

<table>
<thead>
<tr>
<th></th>
<th>lc</th>
<th>lp3</th>
<th>rp3</th>
<th>rp4</th>
<th>rm1</th>
<th>lm3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crown height</td>
<td>25.6</td>
<td>7.6</td>
<td>6.7</td>
<td>8.5</td>
<td>6.7</td>
<td>7.7</td>
</tr>
<tr>
<td>Maximum length of crown</td>
<td>10.3</td>
<td>10.8</td>
<td>10.3</td>
<td>12.3</td>
<td>13.6</td>
<td>--</td>
</tr>
<tr>
<td>Maximum width of crown</td>
<td>9.4</td>
<td>5.8</td>
<td>6.0</td>
<td>8.7</td>
<td>10.5</td>
<td>11.5</td>
</tr>
</tbody>
</table>

The upper right canine (VMNH 1806) is recurved with the crown making up a little less than half of the length of the tooth. There is a prominent wear facet along the anterior margin, as is typical in peccaries. The posterior margin has a sharp, non-serrate cutting edge. A cingulum is present anteriorly on both the lingual and labial surfaces; the cingulum does not extend to the posterior half of the crown. There are a series of fine enamel longitudinal ridges covering the basal 3/4 of the crown.

Table 5. Measurements of tayassuid canine VMNH 1806.

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Overall height</td>
<td>74 mm</td>
</tr>
<tr>
<td>Crown height</td>
<td>31 mm</td>
</tr>
<tr>
<td>Length of crown at base</td>
<td>13 mm</td>
</tr>
<tr>
<td>Width of crown at base</td>
<td>7 mm</td>
</tr>
</tbody>
</table>

The left second metatarsal has a flattened lateral surface, which in life contacted the third metatarsal. This surface extends from the proximal end of the element to a point 14 mm proximal to the distal end. While this specimen is not diagnostic, its size is consistent with other Calvert Formation “Prosthenops” material.

Table 6. Measurements of tayassuid left second metatarsal, VMNH 1805.

<p>| | |</p>
<table>
<thead>
<tr>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Length</td>
<td>100 mm</td>
</tr>
<tr>
<td>Width at proximal end</td>
<td>12 mm</td>
</tr>
<tr>
<td>Length at proximal end</td>
<td>20 mm</td>
</tr>
<tr>
<td>Width at distal end</td>
<td>13 mm</td>
</tr>
<tr>
<td>Length at distal end</td>
<td>15 mm</td>
</tr>
</tbody>
</table>
Family DROMOMERYCIDAE sensu Janis and Manning, 1998
Genus indeterminate.

Referred specimen: VMNH 1778, associated hindlimb material including the distal end of the left femur, both tibiae, and the proximal part of the left metatarsal. Femur and tibiae collected by Greg McKee, March 1999; metatarsal collected by Annabel Goodridge, April 2006 (Figures 6, 7).

These remains were originally reported as a possible protoceratid (Fraser & Dooley, 2000). Even though these remains were collected seven years apart, they were collected from the same excavation pit within a few centimeters of each other. The physical proximity, consistent size and morphology, and similar preservation of these elements indicate that all the remains are likely to be from a single individual.

Only the distal half of the left femur is preserved. The preserved portion is slender and curved. The lateral supercondyloid crest is low, with a deep adjacent supercondylar fossa. There is a small horizontal shelf of bone at the base of the lateral epicondyle that projects laterally at the distal end of the supercondylar fossa. The vascular groove along the posteromedial surface is prominent. There is a deep intercondylar fossa.

The tibiae are long and slender. The lateral condyle and the lateral tubercle of the spine are larger than their medial counterparts. In proximal view the articular surface of the lateral condyle is trapezoidal in outline, while the medial condyle is more triangular. The intercondyloid fossa is rather wide. The tuberosity of the tibial crest has a low transverse ridge separating shallow anterior and posterior depressions. There is a small nutrient foramen on the posterolateral margin about one-third of the shaft length distal to the proximal end of the shaft. There is a single prominent muscular line running along the proximal half of the posterior side of the tibia. There is a moderately pronounced lateral malleolus, with a distinct fossa for articulating with the distal end of the fibula. The proximal part of each fibula is preserved fused to its corresponding tibia as a short ventrally-oriented projection.

The distal part of the left metatarsal is preserved. This is relatively flat on the articular surface, and with a deep groove (between digits III and IV) along the posterior surface, and a shallower groove on the anterior surface. As is typical in dromomerycids, digit III is larger than digit IV, giving the metatarsal an assymetrical appearance.
Both the femur and the right tibia have fine parallel scratches presumably associated with scavenging, most likely by sharks or fish. Many of the marine fossils in the Carmel Church deposits show similar scratches.

In shape, the Carmel Church specimens closely resemble specimens of *Cranioceras* sp. (AMNH 54636, AMNH 54637), *Procricioceras skinneri* (AMNH 31929), and *Pediomeryx* sp. (UF 69946); however, the Carmel Church specimens are only about 75% as large as these specimens. The tibia length of VMNH 1778 is comparable to *Cranioceras granti* of Frick (1937). The questionable diagnostic usefulness of hindlimb material, combined with the poor state of dromomerycid taxonomy (Janis & Manning, 1998; Prothero & Liter, 2006) makes a generic identification impossible.

**Table 7. Measurements of dromomerycid hind limb elements, VMNH 1778.**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of femur across condyles</td>
<td>45 mm</td>
</tr>
<tr>
<td>Maximum length of femur at distal end</td>
<td>52 mm</td>
</tr>
<tr>
<td>Length of left tibia</td>
<td>211 mm</td>
</tr>
<tr>
<td>Length of right tibia</td>
<td>214 mm</td>
</tr>
<tr>
<td>Maximum width of left tibia at proximal end</td>
<td>46 mm</td>
</tr>
<tr>
<td>Maximum width of right tibia at proximal end</td>
<td>48 mm</td>
</tr>
<tr>
<td>Maximum width of left tibia at distal end</td>
<td>29 mm</td>
</tr>
<tr>
<td>Maximum width of right tibia at distal end</td>
<td>29 mm</td>
</tr>
<tr>
<td>Minimum diameter of shaft of left tibia</td>
<td>14 mm</td>
</tr>
<tr>
<td>Minimum diameter of shaft of left tibia</td>
<td>15 mm</td>
</tr>
<tr>
<td>Maximum width of left metatarsal at proximal end</td>
<td>22 mm</td>
</tr>
</tbody>
</table>

**BIOSTRATIGRAPHIC SIGNIFICANCE**

As noted by Tedford & Hunter (1984) and Wright & Eshelman (1987), the presence of land mammals in a marine deposit such as the Calvert Formation allows for the correlation of biostratigraphic zones across terrestrial and marine realms. Gazin & Collins (1950) and Wright & Eschelman (1987) determined that the Plum Point Member of the Calvert Formation correlated with the Barstovian Land Mammal Age.

Previous studies on Carmel Church diatoms by Andrews (1985) indicates that the Calvert Formation at this locality falls with East Coast Diatom Zone (ECDZ) 6 of Andrews (1988). Two of the land mammals preserved at Carmel Church are useful for biostratigraphic correlation: “Prosthennops” *xiphidonticus* and *Calippus* cf. *regulus*. “P.” *xiphidonticus* is known throughout the Barstovian
Dooley: Carmel Church Land Mammals

(Wright, 1998), while *C. regulus* is known from the late Barstovian through the Clarendonian (Hulbert, 1988; Forsten, 1975; Quinn, 1955). This suggests a late Barstovian age for the Calvert Formation at Carmel Church, with an age range of 15.9-12.5 Ma (Carrasco et al., 2005).

In the Chesapeake Group, “*P.* xiphidonticus” has only been reported from Bed 14 of the Calvert Formation (Wright & Eshelman, 1987). Older units in the Calvert produce other tayassuids.” Tayassuid sp. A” of Wright & Eshelman (1987) is found in the Fairhaven Member of the Calvert, while the lower part of the Plum Point Member (Beds 4-12) produces *Cynorca proterva*. Likewise, “*P.* niobarensis” is found in the next higher stratigraphic unit, Bed 17 of the Choptank Formation (Wright & Eshelman, 1987). This indicates that the Calvert bed exposed at Carmel Church correlates with Bed 14 in Westmoreland County, Virginia and Calvert County, Maryland.

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REFERENCES CITED


Cope, E. D., 1868.


Owen, R., 1848. Description of teeth and portions of jaws of two extinct anthracotheroid quadrupeds...with an attempt to develop Cuvier’s idea of the classification of pachyderms by the number of their toes. Quarterly Journal of the Geological Society of London 4:104-141.


