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NEW MARSUPIAL FROM THE EARLY EOCENE OF VIRGINIA

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ABSTRACT—A new species of the marsupial *Peradectes* is described from the early Eocene Nanjemoy Formation of Virginia. It is the first Tertiary marsupial known from the Atlantic Coastal Plain north of Florida. The smallest species of *Peradectes*, it is more closely related to species known from the Western Interior of North America than to contemporaneous European species.

INTRODUCTION

EARLY CENOZOIC marsupials are widely known from Paleocene and Eocene sediments of the Western Interior of North America, the west coast, and Texas, although they are relatively rare elements in most local faunas. In addition, basal Eocene sediments of Mississippi have yielded a few isolated marsupial teeth (Beard and Dawson, 2001, 2009), but until now no other marsupials have been reported from the Early Cenozoic of eastern North America. Eleven genera and 24 species of marsupials are currently recognized from Paleocene and Eocene strata of North America (e.g., Krishtalka and Stucky, 1983b; Korth, 1994, 2008; McKenna and Bell, 1997; Beard and Dawson, 2009; Horovitz et al., 2009). Most specimens consist of teeth or jaws. Judging from their teeth, all were small animals, ranging from shrew-sized to the size of the larger species of the extant mouse opossum *Marmosa* (few of which exceed 100 g; Eisenberg, 1989; Silva and Downing, 1995; Redford and Eisenberg, 1992). They have usually been assigned to the Didelphidae, either as Didelphinae (Crochet, 1979; Krishtalka and Stucky, 1983a, 1983b) or in one of two subfamilies, Peradectinae and Herpetotheriinae (McKenna and Bell, 1997; Korth, 2008). Herpetotheriines have generally been closely allied with Didelphidae, whereas peradectines are sometimes placed in their own family Peradectidae (e.g., Korth, 1994; Case et al., 2005). Recently, the close relationship of both subfamilies to Didelphidae has been questioned (Case et al., 2005; Sánchez-Villagra et al., 2007) because the similarity of their teeth to those of living didelphids may simply be plesiomorphic. The most recent analysis, which includes new cranial data of the peradectid *Mimoperadectes*, places peradectids as the sister taxon of Didelphidae and herpetotheriines outside this clade as the sister group of crown Marsupialia (Horovitz et al., 2009). Regardless of these classificatory differences, Early Cenozoic marsupials are unarguably dentally conservative, and most authors agree that both subfamilies are among the most primitive known marsupials.

This note reports the first Tertiary marsupial known from the Atlantic Coastal Plain north of Florida. It is also the first Early Cenozoic marsupial from the eastern seacoast. It is allocated to a diminutive new species of the widespread genus *Peradectes* and is one of the smallest known marsupials. The specimen was found as two separate jaw fragments in screen-washed concentrate from the early Eocene Fisher/Sullivan site (=Muddy Creek), east of Fredericksburg, Virginia, by Marco N. Gulotta, who kindly brought it to my attention. Concentrate was derived from matrix taken from a small excavation 1–2 m wide. The two fragments are clearly parts of the same right maxilla, which evidently broke apart during screen-washing.

The Fisher/Sullivan site (on private land and now closed to collecting) has produced the only known early Eocene mammal fauna from the east coast of North America. The site is developed in the Potapaco Member of the Nanjemoy Formation, which consists of glauconitic sand deposited in a nearshore marine environment (Weems and Grimsley, 1999). Rose (1999) reported the first Eocene mammals from the site, consisting then of seven specimens (mostly isolated teeth or tooth fragments), each representing a different taxon. Since then the mammal sample has doubled in number of specimens, but the fossil described here represents the first addition to the taxonomic list (Table 1). It is also notable as the best preserved mammal specimen found so far at the Fisher/Sullivan site.

MATERIALS AND METHODS

The specimen described here was compared with original specimens, casts, and/or published illustrations and descriptions of all recognized species of *Peradectes* and of species of other relevant genera of Paleocene-Eocene didelphimorph marsupials. To insure repeatability of measurements, teeth were oriented following Clemens (1966; see also Lillegraven, 1969), i.e., molar length was measured as the greatest anteroposterior dimension parallel to a line through the paracone and metacone; transverse width was the greatest dimension perpendicular to the length. By this procedure, length is measured buccally, width posteriorly. Lillegraven (1976), Rothecker and Storer (1996), and (implicitly) Crochet (1978) also used this method. Unfortunately, not all authors make it clear how they have oriented teeth for mensuration; hence caution is warranted when comparing published measurements. Furthermore, Korth (1994) appears to have used a slightly different orientation, perhaps accounting for the discrepancy between his upper molar proportions (Korth, 1994, table 8) and those reported here.

Figure 1 consists of digital images taken with a Nikon Digital Sight DS-Fi1 camera mounted to a Nikon SMZ-1500 binocular microscope. The specimen was coated with ammonium chloride sublimate to clarify and enhance surface details.

The specimen is catalogued in the Department of Paleobiology, U.S. National Museum of Natural History (USNM), Smithsonian Institution, Washington, D.C.

SYSTEMATIC PALEONTOLOGY

Cohort MARSUPIALIA Illiger, 1811
Magnorder AMERIDELPHIA Szalay, 1982
Order DIDELPHIMORPHIA Gill, 1872
Family PERADECTIDAE Crochet, 1979
PERADECTES Matthew and Granger, 1921
PERADECTES GULOTTAI new species
Figures 1.1–1.5

Diagnosis.—Smallest known species of *Peradectes*: about 15%–50% smaller than other known species of the genus. $M^{2–3}$ wider than long, with weak conules and relatively small stylar

TABLE *1*—Mammalian fauna of the Fisher/Sullivan Site. Number of specimens in parentheses. (Emended from Rose, 1999).

Didelphimorphia
Peradectidae
Peradectes gulottai, n. sp. (1)
Eulipotyphla
Nyctitheriidae
Genus and species unidentified (2)
?Pantolesta
?Pantolestidae
cf. *Palaeosinopa* sp. (1)
Tillodontia
Esthonychidae
cf. *Esthonyx* sp. (2)
Carnivora
Miacidae
Genus and species indeterminate (1)
Condylarthra
Hyopsodontidae
Hyopsodus sp. (2)
Perissodactyla
Isectolophidae
cf. *Homogalax* sp. (3)
?Rodentia
?Ischyromyidae
genus and species indeterminate (1)
Mammalia indeterminate due to heavy abrasion (2)

cusps. $M^{2–3}$ paracone smaller and distinctly lower than metacone; same elevation as, or slightly lower than, protocone. M^2 stylar cusp B largest, A somewhat smaller, and D smallest. M^3 stylar cusp A slightly larger than B, D smallest. Cusp C indistinct on $M^{2–3}$. Ectoflexus moderate on M^2, deep on M^3. Similar in size to *Nanodelphys hunti*, but molars less transverse and stylar cusps better developed than in *N. hunti*.

Description.—The holotype consists of two fragments of right maxilla, one containing $P^{2–3}$ and the margins of the alveoli for P^1 and M^1, the other including $M^{2–3}$ and alveoli for M^1 and the anterobuccal alveolus of M^4. The two can be joined through the alveoli for M^1, leaving little doubt that they belong to the same individual. The lower margin of the orbit is preserved above the molars.

The more anterior fragment has a large infraorbital foramen above the anterior root of P^3. A relatively large infraorbital foramen, which transmits the maxillary nerve (CN V^2), suggests a highly sensitive snout with well developed vibrissae, as is typical of extant didelphimorphs. Two much smaller foramina run rostrally from the anteromedial end of the infraorbital foramen. The more posterior one closely approximates the configuration of the incisivomaxillary canal in placentals, which transmits anterior superior alveolar nerves and vessels to the incisors, canine, and anterior premolars (Evans and Christensen, 1979; Wible, 2008). The anterior foramen may represent an accessory alveolar canal. Deep within the infraorbital canal can be seen a larger foramen, in the floor of the canal, which presumably carried superior alveolar nerves and vessels to P^3 or M^1.

Both the preserved premolars are simple, narrow, two-rooted teeth with one primary cusp. They are relatively low-crowned and triangular in lateral profile, projecting only slightly taller than the molars. Small basal cusps are present anteriorly and posteriorly and are better developed on P^3 than on P^2. A faint lingual cingulum is present on the posterior quarter of P^2. On P^3, short crests extend from the basal cusps both lingually and labially toward the center of the tooth; posteriorly, these crests are continuous with short cingula.

The molars of *Peradectes gulottai*, n. sp., are smaller than those of any other species of the genus: about 15–20% smaller than *P. chesteri* (Gazin, 1952) and *P. californicus* (Stock, 1936), 25–30% smaller than *P. elegans* Matthew and Granger, 1921, and *P. protinnominatus* McKenna, 1960, at least 30% smaller than *P. austrinus* Sigé, 1971, 30–40% smaller than *P. pauli* Gazin, 1956, and *P. louisi* Crochet, 1979, and more than 50% smaller than *P. russelli* Crochet, 1979, and *P. mutigniensis* Crochet, 1979. The two preserved molars are triangular, M^3 slightly more transverse than M^2. The protocone is anteroposteriorly compressed (slightly more so on M^3) and is situated lingual to the paracone rather than more centrally. The paracone of M^2 is distinctly lower and smaller than the metacone. This is true also of M^3, although damage to the metacone makes it appear lower than its original height. The paracone is also lower than the protocone on M^2, but on M^3 the two cusps are of equal height. Very small conules are present on both molars, the paraconule slightly more buccal in position than the metaconule. The preparaconule crista forms a low precingulum that extends to stylar cusp A (the parastyle), though not quite continuously on M^2. Stylar cusp

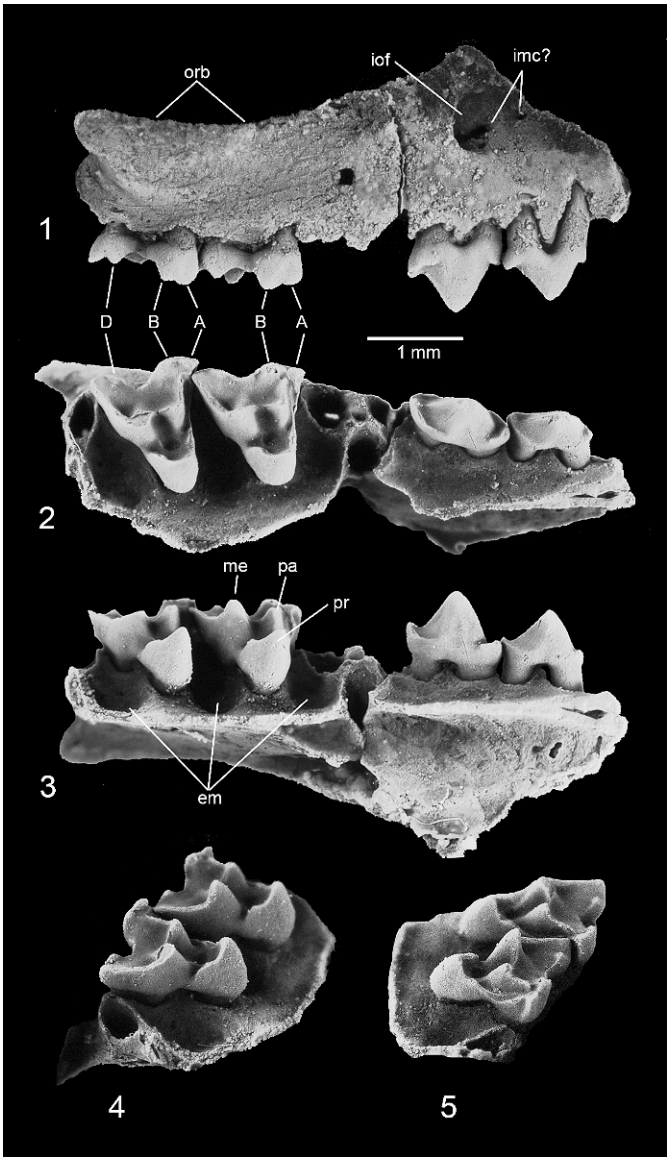

FIGURE *1*—*Peradectes gulottai*, n. sp., holotype, USNM 539469, right maxilla with $P^{2–3}$ and $M^{2–3}$. Letters denote stylar cusps. Abbreviations: em, embrasure pits; imc?, incisivomaxillary canals; iof, infraorbital foramen; me, metacone; orb, orbital rim; pa, paracone; pr, protocone. *1*, lateral; *2*, occlusal; *3*, lingual; *4*, posterior; *5*, anterior.

TABLE 2—Comparison of $M^{2–3}$ dimensions and proportions in *Peradectes* and *Nanodelphys*.

Species	Age[1]	M2L	M2L range	M2W	M2W range	M2 L/W	M3L	M3L range	M3W	M3W range	M3 L/W	Reference
Peradectes gulottai, n. sp.	Wa	1.20		1.35		0.89	1.15		1.45		0.79	this paper
P. elegans	mainly Ti	1.60		1.80		0.89	1.40		1.90		0.74	cast of AMNH 17369
P. pauli[2]	Ti											
P. protinnominatus	Cf-Wa	1.60		1.70		0.94	1.50		1.90		0.79	cast of holotype
P. chesteri	Wa-Br						1.3		1.8		0.72	Gunnell, 1998
P. chesteri	Wa-Br	1.5		1.6		0.94	1.3	1.2–1.4	1.7		0.76	Krishtalka and Stucky, 1984
P. chesteri	Wa-Br	1.7		1.6		1.06	1.4		1.7		0.82	West, 1973[3]
P. californicus	Ui-Du	1.34	1.22–1.50	1.56	1.34–1.79	0.88	1.46	1.21–1.62	1.79	1.59–1.98	0.82	Lillegraven, 1976
P. californicus	Ui-Du						1.34	1.20–1.56	1.76	1.68–1.83	0.76	Rothecker and Storer, 1996
P. louisi	Yp	1.56	1.46–1.66	1.82	1.80–1.83	0.86	1.63		1.87		0.87	Crochet, 1978
P. russelli	Yp	1.88	1.87–1.89	2.10		0.90	2.06	1.97–2.13	2.42	2.28–2.56	0.85	Crochet, 1978
P. mutigniensis	Yp	1.74		2.12		0.82	1.81	1.70–1.90	2.32	2.15–2.44	0.78	Crochet, 1978
P. austrinus[4]	L. Pal.?						1.48		2.48		0.60	Muizon, 1992
Peradectes, cf. *P. austrinus*	E. Pal.						1.8		2.4		0.75	Muizon, 1992
Nanodelphys hunti	Or					0.86					0.75	Korth, 1994

[1] Ages from Korth (2008) for North American species, Crochet (1978) for European species: Br, Bridgerian; Cf, Clarkforkian; Du, Duchesnean; Ti, Tiffanian; Ui, Uintan; Wa, Wasatchian; Yp, Ypresian. Age for localities yielding *P. austrinum* follow Muizon (1992) and Sigé et al. (2004): E. Pal., Early Paleocene; L. Pal., Late Paleocene.

[2] Upper molars of *P. pauli* were briefly described but not figured by Krishtalka and Stucky (1983b), and no measurements were provided. They are said to be slightly larger than those of *P. protinnominatus*.

[3] West (1973) referred these teeth to *Peratherium innominatum* Simpson, 1928, but Krishtalka and Stucky (1983a) transferred them to *Peradectes chesteri*. North American species of *Peratherium* are now considered to represent *Herpetotherium* (Korth, 1994, 2008; Rothecker and Storer, 1996).

[4] Based on the holotype, an incomplete molar. Sigé (1971) reported only the length; Muizon (1992) provided a width measurement as well, but the very low L/W ratio suggests that the width measurement may be too high.

A is a little smaller and lower than stylar cusp B (stylocone) on M^2, but their sizes are reversed on M^3. Stylar cusp D is smaller and lower on both molars than the other stylar cusps. No cusp C is evident. The buccal end of the postmetacone crista is elevated and might therefore be considered a metastyle (stylar cusp E), but no separate cusp is formed. An ectoflexus is present on both molars and is particularly deep and anteroposteriorly shorter on M^3. Distinct embrasure pits, deepening posteriorly, are present between successive molars.

Measurements (L, length; W, width): P^2 L = 0.90, W = 0.35; P^3 L = 1.10, W = 0.50; M^2, L = 1.20, W = 1.35; M^3, L = 1.15, W = 1.45; L/W ratios: M^2, 0.89; M^3, 0.79.

Etymology.—For Marco N. Gulotta of King George, Virginia, who found and donated the holotype.

Holotype.—USNM 539469, right maxillary fragments with $P^{2–3}$ and $M^{2–3}$, only known specimen.

Occurrence.—Fisher/Sullivan Site, east of Fredericksburg, Stafford County, Virginia; early Eocene (Wasatchian NALMA) Nanjemoy Formation, Potapaco Member, Bed B.

Discussion.—The absence of dilambdodonty and of posterolingual expansion of the protocone (characteristics of *Herpetotherium*), together with the weakly developed conules and stylar cusps, clearly place this specimen in *Peradectes*, although its reduced M^2 paracone is more typical of *Herpetotherium*. *Herpetotherium* further differs, however, in typically having cusp C or D most prominent of the stylar cusps (Korth, 2008). In the Nanjemoy specimen, cusp D is diminished and cusp C is absent, which is typical of *Peradectes* (Krishtalka and Stucky, 1983b). The molar proportions of *Peradectes gulottai*, n. sp., resemble those of other *Peradectes* in having both M^2 and M^3 wider than long, and they resemble those of other North American species, except *P. californicus*, in having M^3 relatively shorter and wider than M^2 (Table 2). Although the individual proportions of the two molars are closest to those of *P. californicus*, M^3 of *P. californicus* tends to be larger overall than M^2 (both longer and wider). The European species resemble *P. californicus* and differ from *P. gulottai* in this regard. Nevertheless, the proportional differences among species are not great, and larger samples might well indicate that these small differences are not significant.

Upper premolars are surprisingly rare (or unpublished) in early marsupials. $P^{2–3}$ are well preserved in the holotype of *P. gulottai*, and they appear to be lower crowned than those of *Pediomys cooki* Clemens, 1966, *Peratherium*, or *Herpetotherium* (e.g., Clemens, 1966; Koenigswald, 1970; Crochet, 1978; Sánchez-Villagra et al., 2007). P^2 is also conspicuously lower crowned than that of the peradectine *Mimoperadectes houdei* Horovitz et al., 2009.

Peradectes gulottai is smaller than all other known species of the genus. The next smallest species are *P. chesteri* and *P. californicus*, most of whose linear dimensions average at least 15% larger (Table 2). Besides this distinction, *P. gulottai* generally differs from other species of *Peradectes* in having a more reduced molar paracone and a deeper ectoflexus. Both *P. protinnominatus* and *P. elegans*, the type species, further differ in having a less anteroposteriorly compressed protocone and a distinct stylar cusp C. In addition, *P. elegans* has a more separated paracone and metacone. *Peradectes chesteri*, a Wasatchian species like *P. gulottai*, further differs in having vestigial conules, and vestigial stylar cusps C and D, if these cusps are present at all (Krishtalka and Stucky, 1983a, 1984). In other respects it may be closer morphologically to *P. gulottai* than other species, but linear dimensions of upper molars of *P. chesteri* range from 15%–40% larger than those of *P. gulottai* (Table 2). *Peradectes californicus* and *P. pauli* have both been described as having a less compressed protocone and stronger stylar cusps C and D than in *P. chesteri* (Krishtalka and Stucky, 1983b).

Early Oligocene *Nanodelphys hunti* Cope, 1873 (including *N. minuta* McGrew, 1937, following Korth, 1994), may be mentioned here because it has sometimes been referred to *Peradectes*, and it is close in size to *P. gulottai* ($M^{2–3}$ L = 2.5 mm, McGrew, 1937). In contrast to *P. gulottai*, however, *N. hunti* lacks distinct stylar cusps except for cusp B (Korth, 1994).

The non-North American species of *Peradectes* are all substantially larger than *P. gulottai*. South American *P.*

austrinus differs in having a distinct stylar cusp C (Sigé, 1971). All the European species (*P. louisi*, *P. russelli*, and *P. mutigniensis*) also have a distinct stylar cusp C and further differ from *P. gulottai* in having less transverse upper molars, a less compressed protocone, and a shallower ectoflexus (Crochet, 1978, 1979). *Peradectes louisi* and *P. russelli* resemble *P. gulottai*, however, in having reduced molar paracones.

CONCLUSIONS

Peradectes gulottai, n. sp., adds to the local fauna of the early Eocene Fisher/Sullivan Site and is the first Early Cenozoic marsupial known from the Atlantic Coastal Plain. The only other marsupials of comparable age from the eastern part of North America are a few isolated teeth of *Mimoperadectes sowasheensis* Beard and Dawson, 2009, and *Copedelphys innominata* (Simpson, 1928) (=*Peratherium macgrewi* (Bown, 1979)), reported from the Tuscahoma Formation (Red Hot local fauna) of Mississippi (Beard and Dawson, 2009). These specimens were initially identified as *Mimoperadectes labrus* Bown and Rose, 1979, and the otherwise European species *Peratherium constans* Teilhard de Chardin, 1927 (Beard and Dawson, 2001). Judging from the limited material available, *Peradectes gulottai* is more similar to species known from the Western Interior of North America than to contemporaneous European species. Among North American species of *Peradectes*, *P. gulottai* seems to be most similar in size and morphology to *P. chesteri*, known from the Wasatchian and Bridgerian of Wyoming and Utah. Nevertheless, all the mammalian taxa from the Fisher/Sullivan Site (with the possible exception of cf. *Homogalax* sp.) represent genera common to both North America and Europe, underscoring the close similarity of their faunas during the early Eocene.

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