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JOSHUA X. SAMUELS (2021). The first records of *Sinclairella* (Apatemyidae) from the Pacific Northwest, USA.

Cover: Teeth of *Sinclairella dakotensis* from the John Day Formation of Oregon (JODA 15846, 15850) overlain on a reconstruction of its skull (after Jepsen 1934).
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The first records of *Sinclairella* (Apatemyidae) from the Pacific Northwest, USA

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Apatemyidae are a rare and enigmatic group of small insectivorous mammals that lived in North America and Europe in the Paleogene. The last known apatemyids in North America are two species in the genus *Sinclairella*, known from sites in the Great Plains and Florida. Here, I formally describe an upper second molar and lower incisor of the apatemyid, *Sinclairella dakotensis*, from the incredibly well-studied Turtle Cove Member of the John Day Formation in Oregon. These early Arikareean age specimens represent the first records of the family west of the Rocky Mountains. *Sinclairella dakotensis* filled a 'woodpecking' niche unlike any other mammal known from the region, and its co-occurrence with a number of forest-adapted mammal species is consistent with previous interpretations of environments at the time having been dominated by woodlands.

Keywords: Apatotheria, apatemyid, John Day Formation, Turtle Cove Member, Arikareean

INTRODUCTION

The Apatemyidae (Matthew 1909) are a unique family of mammals uncommonly found from Paleogene localities in North America and Europe. Records include members of six genera, known from the early Paleocene to latest Oligocene of North America and early Paleocene to Eocene of Europe (Koenigswald et al. 2005, 2009, Rose 2006, Gunnell et al. 2008, Silcox et al. 2010, Czaplewski and Morgan 2015, Tornow and Arbor 2017). Despite being relatively rare in the fossil record, a number of apatemyids are known from well-preserved and complete skeletons (Bloch and Boyer 2001, Koenigswald et al. 2005, Silcox et al. 2010), allowing inference of apatemyid ecology based on their anatomy. The cranial, dental, and postcranial remains of apatemyids show convergence with living 'woodpecking' mammals, like the aye-aye (*Daubentonia* Geoffroy 1795, Daubentoniidae Gray 1863) and striped possum (*Dactylopsila* Gray 1858, Petauridae Bonaparte 1838) (McKenna 1963, West 1973, Flannery and Schouten 1994, Soligo 2005, Koenigswald et al. 2005, Rose 2006, Czaplewski and Morgan 2015). Similar cranial, dental, and manus adapatations in apatemyids to those of extant primates and marsupials suggest that they were arboreal insectivores that used their enlarged, procumbent incisors and elongate manual digits to open tree bark and extract insects and their larvae (Koenigswald et al. 2005, Czaplewski and Morgan 2015).

The latest member of the family in North America is the long-lived genus *Sinclairella*. That genus includes two species: 1) *S. dakotensis* Jepsen (1934) from the Duchesnean (middle Eocene) to early Arikareean (Ar1, early Oligocene) of the Great Plains (Jepsen 1934, Clemens 1964, West 1973, Simpson 1985, Pearson and Hogansan 1995, Storer 1995, 1996, Gunnell et al. 2008, Tornow and Arbor 2017), and 2) *S. simplicidens* Czaplewski and Morgan (2015) from the late Arikareean (Ar3, late Oligocene) of the Gulf Coastal Plain of Florida. Here, I formally describe the occurrence of an apatemyid from the Turtle Cove Member of the John Day Formation in Oregon, which was first reported in a conference abstract (Cavin and Samuels 2012). It represents the first record of the family from west of the Rocky Mountains.

MATERIALS AND METHODS

Geological setting and available fossil record

The John Day Formation is distributed across central and eastern Oregon, and contains approximately 1,000 m of strata, mainly volcaniclastic sedimentary rocks and airfall tuffs (Fisher and Rensberger 1972, Robinson et al. 1984, Retallack et al. 2000, Albright et al. 2008,

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McClaughry et al. 2009). These strata are widely geographically variable, but well understood after extensive study for more than 100 years (Merriam 1901, Hay 1963, Fisher and Rensberger 1972, Fremd et al. 1994, Hunt and Stepleton 2004, Albright et al. 2008). Conspicuous marker units and distinctive lithologies of strata allow exposures of the John Day Formation to be correlated at great distances (Albright et al. 2008).

There are three distinct 'facies' described for the John Day Formation: western, southern, and eastern (Robinson et al. 1984). In the vicinity of the Sheep Rock Unit of John Day Fossil Beds National Monument there is a nearly continuous sequence of eastern 'facies' strata preserved (Fig. 1). Recent studies (Hunt and Stepleton 2004, Albright et al. 2008) produced detailed litho- and chronostratigraphy for the John Day Formation, combined with radioisotopic and paleomagnetic calibration (Albright et al. 2008). The John Day Formation, as currently defined, has seven members that range from middle Eocene to early Miocene in age, about 39 to 18 Ma (Hunt and Stepleton 2004, Albright et al. 2008).

The teeth described here originate from the Turtle Cove Member of the John Day Formation (Fisher and Rensberger 1972). The Turtle Cove and overlying Kimberly Members have been divided into lithostratigraphic units A–M, based on the individual lithologies of beds and interspersed tuffs (Fremd et al. 1994, Albright et al. 2008). Among the dozen Turtle Cove Member tuffs that have been radiometrically dated using $^{40}Ar/^{39}Ar$ single-crystal laser-fusion are the A-B Tuff, dated 29.75 ± 0.02 Ma, and the Blue Basin Tuff, dated 28.8 Ma, which bracket the strata from which the specimens described here originate (Fig. 2, Albright et al. 2008).

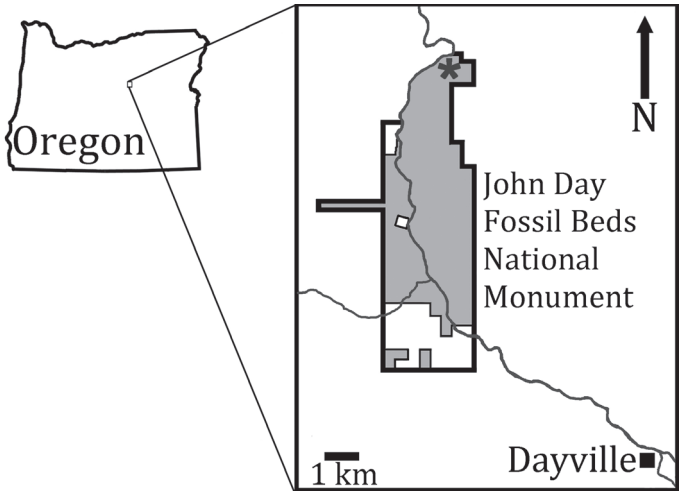

Figure 1. Map of Oregon (left) showing the location of Blue Basin (asterisk) within the Sheep Rock Unit of John Day Fossil Beds National Monument, Grant County, Oregon. The dark border represents the congressional boundary of the monument and shaded gray area indicates National Park Service property.

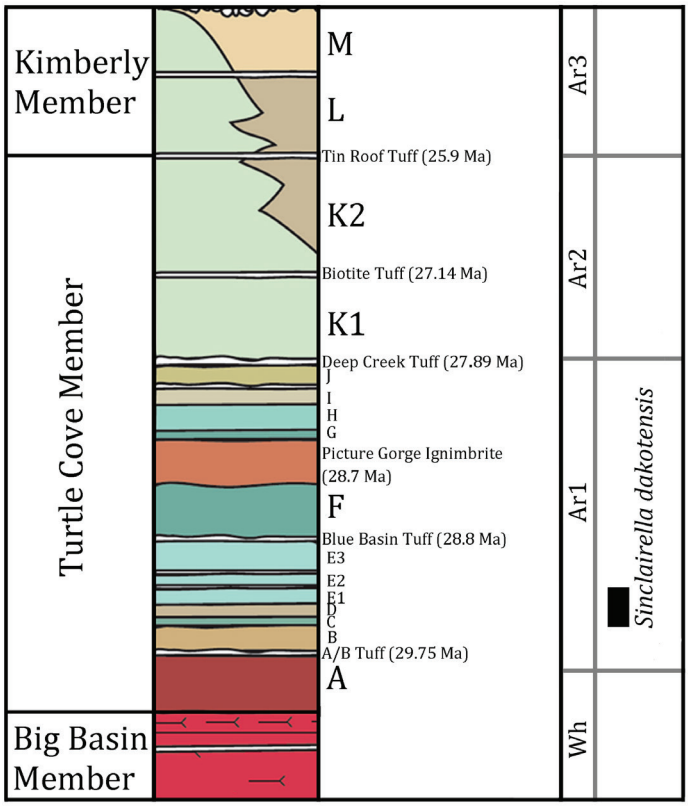

Figure 2. Composite stratigraphic section of the John Day Formation near Sheep Rock with stratigraphic positions of *Sinclairella dakotensis* specimens. Stratigraphy and radiometric dates are based on Albright et al. (2008) and Fremd (2010).

Dental nomenclature, comparative material, and measurements

The specimens described here, JODA 15846 and 15850, are housed in the collection of John Day Fossil Beds National Monument (JODA). Precise locality information for specimens is on file at JODA. Specimens were photographed using a Dino-Lite Edge AM4815ZT digital microscope camera. Measurements were taken using Mitutoyo Absolute digital calipers to the nearest 0.01 mm. Measurements of the upper second molar, M2, include maximum anteroposterior length and mediolateral width taken at the occlusal surface (Width 1), as well as three additional width measurements used in several recent studies (Koenigswald et al. 2009, Czaplewski and Morgan 2015): Width 2 is the diagonal length from the lingual margin of the protocone to the labial margin of the paracone; Width 3 is the diagonal length from the lingual margin of the protocone to the labial margin of the metacone; and Width 4 is the diagonal length from

the posterolingual corner of the talon at the hypocone to the anterolabial corner of the tooth at the parastyle.

Dental nomenclature and descriptive terminology follows Van Valen (1966) and Silcox et al. (2010). Upper and lower teeth are designated by a letter followed by a number indicating their position within the tooth row. The upper teeth, in this case molars, are designated using capital letters (e.g., M2), the lower teeth, in this case an incisor, with lowercase letters (e.g., i1). The specimens described here were compared to casts of fossils at several institutions, as well as published photographs, drawings, and measurements in several studies including: Jepsen (1934), Scott and Jepsen (1936), Hough and Alf (1956), Clemens (1964), Czaplewski and Morgan (2015), and Tornow and Arbor (2017).

Institutional abbreviations

JDNM, John Day Fossil Beds National Monument (locality number), Kimberly, OR; **JODA**, John Day Fossil Beds National Monument (museum collection), Kimberly, OR; **KU**, University of Kansas Museum of Natural History, Lawrence, KS; Princeton Museum, Princeton, NJ; **RAM**, Raymond Alf Museum, Webb School of California, Claremont, CA; **UCM**, University of Colorado Museum, Boulder, CO; **UMPC**, University of Montana Paleontology Center, The University of Montana, Missoula, MT.

SYSTEMATIC PALEONTOLOGY

APATOTHERIA Scott and Jepsen, 1936
APATEMYIDAE Matthew, 1909
SINCLAIRELLA Jepsen, 1934
Sinclairella dakotensis Jepsen, 1934
Fig. 3, Table 1

Referred specimens—JODA 15846, lower right incisor; JODA 15850, upper right second molar.

Occurrence—JODA 15846: locality JDNM 9, Blue Basin (Turtle Cove), Grant County, OR, Unit C, Turtle Cove Member, John Day Formation; JODA 15850: locality JDNM 9, Blue Basin (Turtle Cove), Grant County, OR, Unit E1, Turtle Cove Member, John Day Formation.

Age—Early early Arikareean (Early Oligocene, Ar1), between A-B Tuff dated 29.75 ± 0.02 Ma and Blue Basin Tuff dated 28.8 Ma (Albright et al. 2008).

Description

M2—JODA 15850 (Fig. 3A, B) is an upper right second molar, trapezoidal in shape and slightly wider than it is long (Table 1). It bears four cusps, with a large paracone and slightly smaller metacone on the labial side, and a similarly sized protocone and hypocone on the lingual side. The cusps are all brachydont and show relatively little wear, though the paracone and hypocone are more worn than the metacone and protocone. The paracone is oval and the metacone is relatively triangular in outline, and both cusps are somewhat mediolaterally compressed. The paracone and metacone are connected by a short, continuous, and relatively straight crest (centrocrista). Small crests extend from the anterior margin of the paracone (preparacrista) and posterior margin of the metacone (postmetacrista), these are continuous with the centrocrista and form a somewhat zig-zag line. A distinct, irregular stylar shelf runs from anterior margin of the paracone, along the labial surface of the tooth (at the preparacrista), and extends to the posterior surface of the metacone, ending at the posterolabial corner of the hypocone. A small, but distinct projection of the stylar shelf extends from the anterolabial surface of the paracone, and a similar projection lies on the labial surface of the metacone. While the stylar shelf bears several minute cuspules, none represent a clear parastyle or metastyle. The protocone is large and relatively anteriorly placed, with the apex slightly anterior to the midpoint of the labial cusps, in line with the posterior part of the paracone. A deep trigon basin separates the protocone from the paracone and metacone. A distinct anterior arm (preprotocrista) extends from the anterolabial corner of the protocone and ends along the anterior margin of the paracone. Posterior to the trigon is a large talon, bounded lingually by a prominent, crescentic hypocone, which lies posterior and lingual to the protocone. A relatively large crest (prehypocrista) runs anteriorly from the hypocone, extending all along the lingual surface of the protocone. Another crest (posthypocrista) runs posterolingually from the hypocone, ending along the posterior margin of the metacone. The posterior and lingual margins of the molar are straight, while the anterior margin is convex adjacent to the paracone, and the labial margin is slightly concave between the stylar projections with a shallow ectoflexus.

i1—JODA 15846 (Fig. 3C) is a lower right incisor that is missing its anterior end. It is mediolaterally narrow with a maximum mediolateral width of 2.39 mm and dorsoventrally deep, tapering anteriorly in lateral view with a maximum depth of 4.87 mm at the posterior end and maximum depth of 2.91 mm at the anterior end. Enamel is present on the ventral and lateral surfaces, but missing from the medial and dorsal surfaces. There is an elongate and curved wear-facet on the dorsal surface. A large pulp cavity is evident within the broken posterior

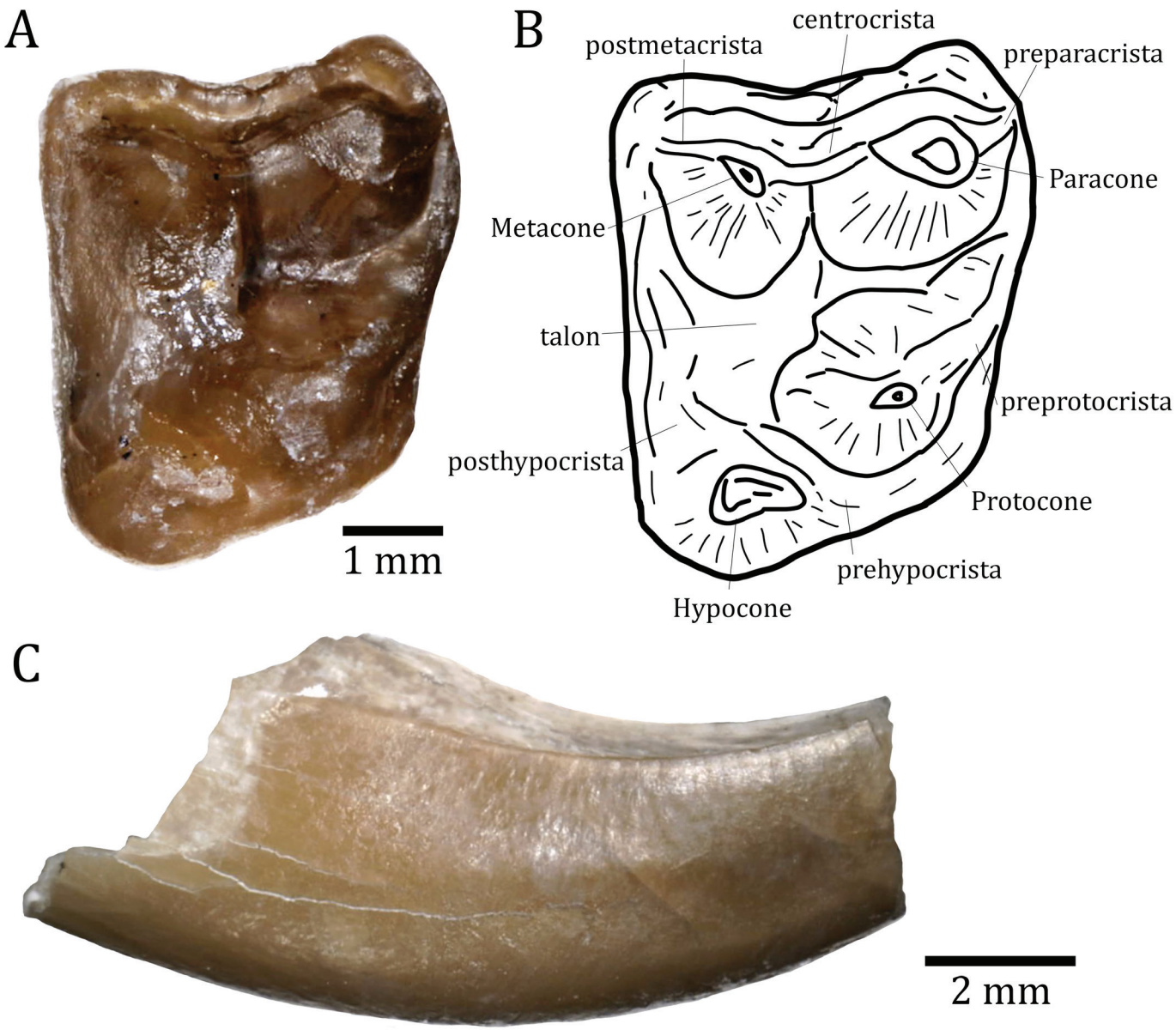

Figure 3. *Sinclairella dakotensis* from the Turtle Cove Member of the John Day Formation. **A**. Upper right second molar (M2) in occlusal view, JODA 15850. **B.** Illustrative drawing of JODA 15850 shown in **A** detailing morphology. **C**. Lower right incisor (i1) in lateral view, JODA 15846.

end of the tooth.

Comparisons

Both the John Day lower incisor (JODA 15846) and M2 (JODA 15850) show features typical of the Apatemyidae. The incisor bears the distinctive shape of apatemyids: elongate, anteriorly tapered, and dorsoventrally deep (Jepsen 1934). As in other described apatemyids, the upper molar is low crowned, bears a hypocone, lacks conules, and has a prominent labial stylar shelf.

The M2 falls within the size range of *Sinclairella dakotensis* and is clearly larger than any known specimens of *S. simplicidens* (Czaplewski and Morgan 2015, Tornow and Arbor 2017) (Table 1). As is typical of *S. dakotensis*, the M2 trigon cusps are subequal in size and the hypocone is large, similar in size to the protocone (Silcox et al. 2010, Czaplewski and Morgan 2015, Tornow and Arbor 2017). The crests between cusps in JODA 15850 are well developed and valleys between cusps are deep, as in other described specimens of *S. dakotensis* (Czaplewski and Morgan 2015, Tornow and Arbor 2017). Additionally, the labial stylar shelf of JODA 15850 has distinct projections anterolabial to the paracone and labial to the metacone, but no distinct parastyle or metastyle,

as has previously been observed in *S. dakotensis* and other early apatemyids (Clemens 1964, Czaplewski and Morgan 2015, Tornow and Arbor 2017). While there is a clear preprotocrista in JODA 15850 extending from the anterolabial corner of the protocone, there is no distinct paraconule, as was present in the M2 recently described from the Sand Creek anthills in Nebraska (Tornow and Arbor 2017). The ectoflexus of JODA 15850 is also relatively shallow in comparison to some other described specimens of *S. dakotensis* from Colorado and Nebraska (Clemens 1964, Tornow and Arbor 2017). The talon of JODA 15850 is large, as in previously described specimens of *S. dakotensis*, and the hypocone is relatively larger and more prominent than in some described specimens of this species (e.g., UMPC 14862, Tornow and Arbor 2017). The other named species, *S. simplicidens*, has a smaller hypocone, smooth bottom valleys between cusps, less prominent crests between cusps, and lacks the prominent labial stylar shelf and projections seen in JODA 15850 and other specimens of *S. dakotensis* (Czaplewski and Morgan 2015, Tornow and Arbor 2017).

DISCUSSION

Both of the teeth collected from the Turtle Cove Member of the John Day Formation are identified as *S. dakotensis*. The size and morphology of the M2 and lower incisor from Oregon (Table 1, Fig. 3) are consistent with previously described specimens of *S. dakotensis*, and differentiable from other known apatemyids. This discovery extends the geographic range of *S. dakotensis*, representing the first record of an apatemyid in North America west of the Rocky Mountains. It also confirms widespread survival of this species into the early Arikareean, which was previously reported from the Duchesnean to early Arikareean of the Great Plains (Gunnell et al. 2008). As Czaplewski and Morgan (2015) recently described *S. simplicidens* from Florida, these records indicate survival of apatemyids on a broad geographic scale into the Arikareean of North America.

The mammalian faunas of the Oligocene of Oregon are very well-known, particularly the Turtle Cove Member of the John Day Formation (e.g., Albright et al. 2008, Fremd 2010, Korth and Samuels 2015, Samuels et al. 2015). Finding an apatemyid from the John Day Basin demonstrates that even well-studied sites have potential for new discoveries. The lifestyle of apatemyids is also rather different than any other known mammal from the region at this time, representing a new ecological niche, 'woodpecking', for the Oligocene of Oregon. Several extant mammals, with the most well-known being the aye-aye (*Daubentonia*) and striped possum (*Dactylopsila*), are known for feeding on wood-boring beetle larvae, which they acquire using percussive foraging with an elongate digit and bark stripping with enlarged, ever-growing incisors (Erickson 1991, Sterling 1994, Koenigswald et al. 2005, Morris et al. 2018). The similar elongate fingers, craniodental structure, and ecology of this living primate and marsupial have been compared to known skeletons of apatemyids and used to infer similar ecological niches for these organisms (Koenigswald et al. 2005, Czaplewski and Morgan 2015), which are sometimes called 'mammalian woodpeckers'.

The presence of an apatemyid in the lower part of the Turtle Cove Member (units C and E1) also supports reconstruction of the area as forested at that time. Unit C of the Turtle Cove Member also includes several other forest-adapted taxa, specifically the tree squirrel *Miosciurus covensis* Korth and Samuels (2015) and the clawed oreodont *Agriochoerus antiquus* Leidy (1850) (Lander 1998, Albright et al. 2008). Similarly, unit E1 has two tree squirrel species, *M. covensis* and *Protosciurus mengi* Black (1963), as well as *A. antiquus*. There is a clear ecological transition higher the Turtle Cove Member, with some forest-adapted taxa vanishing near the Picture Gorge Ignimbrite and open-habitat adapted taxa, burrowing rodents and cursorial leporids, becoming more common

Table 1. Measurements of *Sinclairella* teeth. Data for *S. dakotensis* derived from Clemens (1964) and Tornow and Arbor (2017). Data for *S. simplicidens* from Czaplewski and Morgan (2015). Dimensions in mm.

Species	Specimen	M2 Length	M2 Width	Width 2	Width 3	Width 4
S. dakotensis	JODA 15850	3.58	4.08	3.73	3.94	5.39
S. dakotensis	Princeton 13585	3.4	4.7			
S. dakotensis	RAM 1674	3.4	4.2			
S. dakotensis	KU 11210	3.8	4.1			
S. dakotensis	UCM 21073	3.6	4.1			
S. dakotensis	UMPC 14862	3.73	4.63			
S. simplicidens (n=2)	UF 97383, 97384	2.80–2.84	2.68–3.04	3.10–3.20	2.90–3.10	3.70–3.80

(Korth and Samuels 2015). Unit E1 is the stratigraphically lowest occurrence of an open-habitat adapted rodent, the burrowing beaver *Palaeocastor peninsulatus* Cope (1881). The absence of *S. dakotensis* above unit E1 may be a simple consequence of their rarity overall, but may reflect the fact that as conditions became cooler and drier through the early Oligocene, the region's forests gave way to more open habitats, while bunch grasses and shrubs became more common (Retallack et al. 2000, Sheldon et al. 2002, Retallack 2007). The persistence of some wooded areas into the late Arikareean (Ar3) is supported by the presence of tree squirrels, *Miosciurus ballovianus* Cope (1881), *Pr. mengi*, and *Pr. rachelae* Black (1963), and a primate, *Ekgmowechashala zancanellae* (Samuels et al. 2015), but the most abundant mammals from that time in Oregon are burrowing entoptychine geomyids, palaeocastorine beavers, and archaeolagine leporids (Korth and Samuels 2015). Combined, these faunal records support interpretation of the lower part of Turtle Cove (units A to D) as relatively heavily forested and the middle and upper parts (units E to K2) as a mosaic open woodland environment.

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