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A NEW RODENT FAUNA FROM THE UPPER PORTION OF THE BRULE FORMATION AT FITTERER RANCH (OLIGOCENE, WHITNEYAN), SOUTHWESTERN NORTH DAKOTA

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ABSTRACT

Screen washing 398 kg of rock from a newly sampled bed within the Brule Formation at the Fitterer Ranch paleontological localities (Whitneyan, Oligocene) produced 134 rodent specimens that comprise the youngest local fauna yet described from there: Fitterer Ranch Fauna D. Ten rodent taxa are recorded including the first reports of the aplodontid *Disallomys* sp., cf. *D. storeri* and the cricetid *Scottimus kellamorum* from North Dakota. Additionally, the sciurid *Sciurion jamesi* is recognized in both Fitterer Ranch Fauna C and D based on review of previously described specimens and new material. Eleven rodent species previously reported from older levels at Fitterer Ranch (Fitterer Ranch Faunae A-C) are not present in Fitterer Ranch Fauna D. Six of these taxa are rarely sampled within older fauna, perhaps explaining their absence in this younger site, five of those species are abundant within the older faunae, suggesting they are either absent from Fitterer Ranch Fauna D or their relative abundance had substantially decreased. Comparison to Obritsch Ranch Fauna B, which is situated at a similar stratigraphic position at the nearby Obritsch Ranch locality, reveals that the relative diversity of rodents in the two faunae was broadly similar, though only three of the twenty total species documented are present within both faunae. The relative abundance of heliscomyid specimens within Fitterer Ranch Fauna D (1%) is much lower than in Obritsch Ranch Fauna B (32%) and the slightly older Fitterer Ranch Fauna C (15%), more closely resembling that reported from other Whitneyan assemblages in South Dakota (Blue Ash and Cedar Pass local faunae).

INTRODUCTION

The most recent study of rodent fossils from the Brule Formation at Fitterer Ranch locality in Stark County, North Dakota, identified 18 species and tracked their local stratigraphic distributions within seven discrete sampling intervals (Korth et al., 2019a). Few rodent specimens were reported from the highest sampling interval (sampling interval 7), with only one rodent species identified, the cricetid *Eumys brachyodus*, based on fewer than five specimens (Korth et. al, 2019a: table A13). The lack of specimens from sampling interval 7 results from the fact that outcrops of the upper portions of the Brule Formation at Fitterer Ranch have steep weathering profiles, making surface collection of vertebrate fossils difficult. To circumvent that problem and improve the knowledge of the age and composition of the vertebrate fauna of the upper portion of the Brule Formation, 398 kg of rock were collected in the fall of 2020 from a fossiliferous bed within sampling interval 7 (Figure 1). These rocks were processed using aqueous screen-washing, resulting in the recovery of hundreds of vertebrate fossils, including over 130 identifiable rodent specimens. In this study this new rodent fauna is described with comparisons to the rodents previously reported from Fitterer Ranch and other localities within the Great Plains Region are provided.

GEOLOGICAL SETTING

The Chadron and Brule Formations at the Fitterer Ranch paleontological locality were informally divided into six numbered units by Skinner (1951), most of which were also divided into lettered subunits (see Korth et al., 2019a: fig. 1). That system was used to track the stratigraphic positions of specimens collected by Skinner's field crew over multiple expeditions. Korth et al. (2019a) defined seven sampling intervals within the Brule Formation at Fitterer Ranch and provided correlations with the subunits of Skinner (1951). Sampling interval 6 consists of specimens recovered from a highly fossiliferous 'local channel' that is eroded down into previously deposited rocks of the Brule Formation in one location at Fitterer Ranch. Although there is some disagreement on the exact stratigraphic placement of that 'local channel' within Skinner's subunits (see Czaplewski et al. [2019] for discussion), it is positioned within the lower half of the Brule Formation at Fitterer Ranch, below the prominent '1st banded layer' that marks a distinct increase in the weathering profile of the Brule Formation at Fitterer Ranch (Skinner, 1951). All specimens collected from the Brule Formation upward from the '1st banded layer' and extending through the remainder of unit six were included in sampling interval 7 (Korth et al., 2019a).

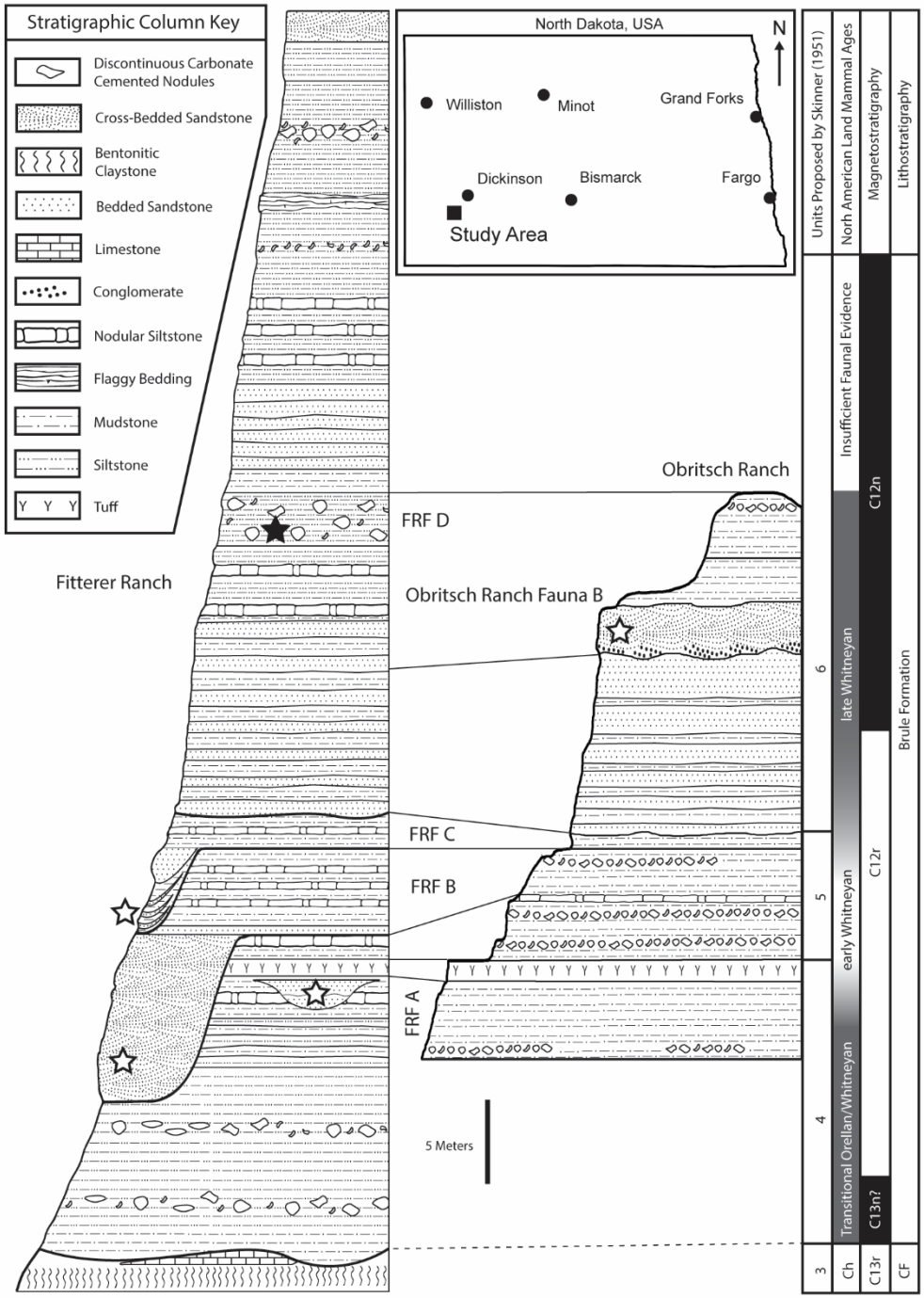

FIGURE 1. Correlated stratigraphic sections of the Brule Formation rocks exposed at the Fitterer Ranch and Obritsch Ranch paleontological localities within Stark County, North Dakota. Modified from Korth et al. (2021). Black star indicates the stratigraphic position of the bed sampled via screen washing in this study. White stars indicate the stratigraphic positions of other localities sampled via screen washing in this area. On the right-hand side of the stratigraphic columns the following data are presented from left to right: unit numbers defined by Skinner (1951), the inferred North American Land Mammal Ages (NALMAs) based on the studies of Korth et al. (2019a, b), the magnetostratigraphic data of Prothero (1996, fig. 5), and the lithostratigraphic boundaries. Gradual shading for the biostratigraphic data reflects uncertainty in the exact position of the transitions between NALMAs. Geographic location of the study area shown in upper right inset map. A key to lithologies and sedimentary structures is provided at the upper left. Abbreviations: C, Chron; CF, Chadron Formation; Ch, Chadronian NALMA; FRF, Fitterer Ranch Fauna; n, normal polarity; r, reverse polarity.

Additional work on micromammal fossils in this area of Stark County by Korth et al. (2019b, 2021, 2023) resulted in the recognition of four stratigraphically stacked local faunae: Fitterer Ranch A, B, and C and Obritsch Ranch Fauna B. Fossils assigned to Obritsch Ranch Fauna B were collected from a distinct, green sandstone that truncates the upper portion of the '1st banded layer' and the silty mudstone above that green sandstone (Korth et al., 2019b), making those fossils clearly younger than those from Fitterer Ranch Fauna C. Prior studies on the rodents and marsupials did not place specimens collected from sampling interval 7 at Fitterer Ranch within one of these four faunae given the small number of available specimens. However, recent work describing the taxonomy and stratigraphic distribution of leptictids and lipotyphlans from the Fitterer Ranch and Obritsch Ranch paleontological localities recognized that the stratigraphic positions of specimens collected from sampling interval 7 at Fitterer Ranch made it likely that they correlated both stratigraphically and temporally with Obritsch Ranch Fauna B rather than Fitterer Ranch Fauna C (Korth et al., 2023). Therefore, the new fauna described here is designated the Fitterer Ranch Fauna D, the youngest fauna yet described from the Fitterer Ranch area.

MATERIALS AND METHODS

Screen Washing Methodology—In the fall of 2020, 398 kg of rock were collected from a silty mudstone that is positioned stratigraphically within subunit 6C of Skinner (1951) at Fitterer Ranch. That rock was divided into 80 subsamples (76 samples of 5 kg, 4 samples of ~4.4 kg) and each subsample was subjected to aqueous screen washing. The weight of the subsamples was determined during prior work by the North Dakota Geological Survey on screen washing of sediment from the White River Group to be the optimal amount of rock for each screen box, allowing breakdown of the rock without overloading and sinking or clogging them. The screen boxes used brass screen with gaps of 0.54 mm between the wires (30 mesh). Brass screen was used because the interwire spacing is more consistent and less prone to bending and creating larger gaps. This spacing was also determined by prior work by the NDGS that showed that screen with larger spacing leads to the loss of some of the smallest microvertebrates fossils (e.g., heliscomyid teeth).

Once subsamples were placed in screen boxes, the boxes were floated in an ovate watering trough equipped with a custom aeration system that maintains gentle, continuous movement of the water in the trough. Screen boxes were floated for seven days, then removed from the water, gently rinsed under running water to remove any remaining fine particulates, then placed on a drying rack for another seven days. Once dry, the remaining rock, referred to as concentrate, was removed from the boxes and gently dry–sieved to separate four different size classes. Sieving the concentrate into different size classes makes picking fossils out of the concentrate much easier as large pieces of rock do not obscure smaller fossils. The size classes were as follows: > 16 mm (coarse fraction); between 16 mm and 8 mm (medium fraction); between 8 mm and 2 mm (fine fraction), and less than 2 mm (extra fine fraction). Each size class from each subsample was then weighed with a digital scale to assess the breakdown of the original sample size. Overall, 92.3% of the original rock washed through the screens, leaving ~30.6 kg of concentrate. Of that concentrate, 67% (20.6 kg) was within the extra fine fraction and 26% (7.9 kg) was within the fine fraction, the ideal size fractions for recovering isolated mammalian teeth and partial jaws.

The concentrate was examined under a stereoscopic microscope, first using standard light, then by a second examination using ultraviolet (UV) light to identify and recover all fossils present. UV light is useful for easily identifying mammalian teeth from these rocks as they brightly fluoresce a yellow or orange color that makes it easier to locate even small pieces of mammalian tooth enamel in the concentrate (see Croft et al., 2004). However, we note that isolated bones and reptilian teeth from this site typically do not strongly fluoresce under UV light, requiring examination under standard light to recognize and remove those fossils from the concentrate.

This work resulted in the recovery of 143 mammalian jaws and isolated teeth that could be identified at least to family. Thus, an identifiable mammalian fossil was recovered for every 2.8 kg of rock that was screen washed, or every 214 grams of concentrate examined. Though the abundance of identifiable mammalian fossils from this rock unit is less than at some of the other stratigraphic intervals we have washed at Fitterer Ranch, the fact that over 90% of the rock from this unit completely broke down with most of the remaining concentrate within the fine or extra fine fractions, facilitated the recovery of sufficient numbers of identifiable mammalian fossils to permit assessment of this fauna.

Terminology—*Dental Terminology*: most dental terminology is based on Wood and Wilson (1936), though castorid terminology is from Stirton (1935). *Stratigraphic Terminology*: Sampling intervals cited in

this study correspond to those used by Korth et al. (2019a, 2019b, 2021) and were based on the stratigraphic units first defined by Skinner (1951) for the White River Group at Fitterer Ranch. Unlike in Korth et al. (2023), we erect a new local fauna, Fitterer Ranch Fauna D, for specimens collected from sampling interval 7 at Fitterer Ranch rather than associating those specimens with Obritsch Ranch Fauna B. *Biostratigraphic Terminology*: The North American Land Mammal Ages (NALMA) used in this study follow the terminology and definitions of Prothero and Emry (2004).

Measurements—All measurements taken with an optical micrometer to the nearest 0.01 mm.

Abbreviations—*Dental Abbreviations*: P/p, upper/lower premolar; M/m, upper/lower molar. *Measurement Abbreviations*: L, anteroposterior length; W, transverse width. *Institutional Abbreviations*: MCZ, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts; NDGS, North Dakota State Fossil Collection, North Dakota Geological Survey, Bismarck, North Dakota; SDSM, South Dakota School of Mines and Technology, Museum of Geology, Rapid City, South Dakota; USNM PAL, United States National Museum of Natural History, Smithsonian Institution, Washington, District of Columbia.

SYSTEMATIC PALEONTOLOGY

Order Rodentia Bowdich, 1821
Family Aplodontidae Brandt, 1855
Subfamily Prosciurinae Wilson, 1949
Genus *Disallomys* Korth, 2009
Disallomys sp., cf. *D. storeri* (Tedrow and Korth, 1997)
Figures 2A, B; Table 1

Allomys storeri Tedrow and Korth, 1997

Referred Specimens—NDGS 12675, NDGS 12676, right M1 or M2; NDGS 12673, right m1.

Description—NDGS 12676 appears to be an upper molar but is heavily worn and a portion of the posterolabial corner is broken off. However, the M1 or M2 (NDGS 12675) is little-worn and complete. It is nearly identical to those described for the holotype. The crown is covered with numerous, low and irregular lophules that are much lower than the major lophs. The buccal cusps (paracone, metacone) are labially flattened; the ectoloph is complete across the entire tooth and connected to the labially flattened mesostyle. There is an anteroposteriorly compressed, small parastyle at the anterolabial corner of the tooth. The anterior cingulum runs directly lingually from it, ultimately ending in a small cuspule along the anterior slope of the protocone. There is a distinct lophule extending lingually from the mesostyle, ultimately joining the smaller, more labial metaconule, just lingual to the base of the metacone. The protoloph is continuous from the paracone to the protocone with a single, central protostyle. The metaloph ends at the lingual (and larger) of the two metaconules. The protocone is crescentic and transversely compressed. There is a minute protocone crest. The hypocone is very small at the posterolingual corner of the tooth. It is continuous anteriorly with the posterior slope of the protocone and posteriorly along the posterior margin of the tooth, touching the posterolabial corner of the metacone.

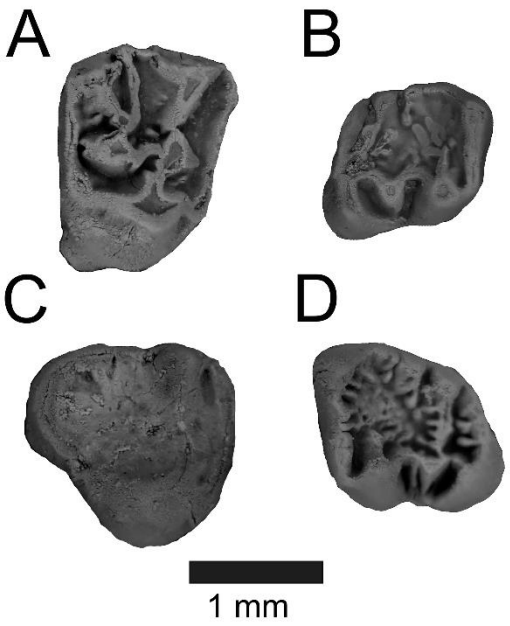

FIGURE 2. Molars of *Disallomys* and *Sciurion* from Upper Fitterer. A-B, *D.* sp., cf. *D. storeri*. A, NDGS 12675, right M1 or M2. B, NDGS 12673, right m1 or m2. C, D, *Sciurion*. C, *S. jamesi*, NDGS 9590, right M3. D, *S.* cf. *jamesi*, NDGS 12674, left m3. All figures to same scale.

The referred m1 (NDGS 12673) is smaller than the m1 of the holotype of *D. storeri* (Tedrow and Korth, 1997: table 3) but markedly similar in morphology. The tooth is wider posteriorly than anteriorly. The metaconid is the tallest of the cusps and conical in shape at the anterolingual corner of the tooth. The anterior cingulid (metalophulid I) extends labially from it and tapers to a point, just anterior to the anterior margin of the protoconid. The protoconid is larger than the metaconid. The posterior arm of the protoconid (metalophulid II) blocks the posterior side of the trigonid, extending lingually to the posterolabial base of the metaconid. The talonid basin is filled with minor, irregular lophules. The ectolophid arches lingually between the protoconid and mesoconid, and again between the mesoconid and hypoconid. The mesoconid is smaller than the other

TABLE 1. Dental measurements of aplodontids, and castorid from Fitterer Ranch Fauna D, Fitterer Ranch, North Dakota. Measurements in mm. Abbreviations: –, tooth broken (unmeasurable); *****, M1/m1 or M2/m2.

Altasciurus leonardi

NDGS #	m1L	m1W	m2L	m2W	m3L	m3W
4325			1.62	1.90	1.98	1.50
4308	1.64	1.59				

Disallomys cf. *storeri*

NDGS #	M1L*	M1W*
12675	1.76	2.19
12676	–	–

NDGS #	m1L*	m1W*
12673	1.65	1.57

Agnotocastor praetereadens

NDGS #	p4L	p4W	m1L	m1W
4307	4.16	3.75	3.16	3.42

NDGS #	P4L	P4W	M1L	M1W	M2L	M2W	M3L	M3W	P4-M3L
4306	3.86	4.52	2.98	3.98	2.82	3.83	2.47	3.49	12.63

labial cusps. The hypoconid is long and obliquely compressed. The anterolabial corner of the hypoconid extends anteriorly, sloping ventrally, nearly reaching the labial border of the mesoconid. The metastylid crest extends posteriorly from the metaconid along the lingual edge of the tooth, ending in a small but distinct metastylid. There is a deep valley separating the metastylid from the hypoconid. The hypolophid extends posterolabially from the hypoconid, joining the posterior cingulid at its center. The posterior cingulid is a high ridge (hypoconulid) running long the posterolingual margin of the lingual half of the tooth, and ending just before the posterior margin of the hypoconid.

Discussion—*Allomys storeri* was originally named by Tedrow and Korth (1997) from the Whitneyan of northwestern South Dakota and was later considered to represent a new genus (*Disallomys*) as the type species (Korth, 2009). The specimens described here are only the second report of this species, extending the geographic range into southwestern North Dakota. These specimens differ from the holotype only in being slightly smaller (Table 1; Tedrow and Korth, 1997: table 3). Owing to this slight difference in size, the North Dakota specimens are provisionally referred to the type species, but they are clearly referable to *Disallomys*.

Genus *Altasciurus* Korth and Tabrum, 2017
Altasciurus leonardi Korth et al., 2019a
Figure 3; Table 1

Referred Specimens—NDGS 4308, right dentary with i1, m1; NDGS 4325, partial left dentary with m2-m3.

Discussion—This species has been fully described elsewhere (Korth et al., 2019a). The specimens reported here differ little from the previous description of the species. The only slight variation is the lack of a second metastylid on the m2 (Figure 3C) and the shorter M3 of NDGS 4325. In all other reported specimens, there is a second metastylid on all lower molars; however, the metastylid is doubled on m3 of this specimen. The length of the m3 of this specimen (1.75 mm) is less than any of those originally reported (Korth et al. 2019a: table A3) but differs from the lowest measurement of the original sample by only 0.05 mm and does not significantly alter the coefficient of variation for this measurement. Previously, this species was limited to Sampling intervals 2, 5, and 6 at Fitterer Ranch (Fitterer Ranch Faunae A, B, and C, respectively).

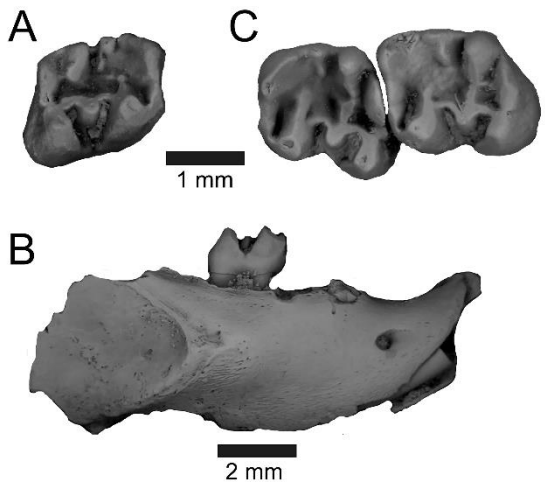

FIGURE 3. Dentary and molars of *Altasciurus leonardi* from Upper Fitterer. A, B, NDGS 4308. A, right m2, occlusal view. B, lateral view of dentary. C, NDGS 4325, left m2-m3, occlusal view. A and C to same scale (above), C to different scale (below).

Family Sciuridae Fischer de Waldheim, 1817
Genus *Sciurion* Skwara, 1986

Discussion—Recently, Bell et al. (2023) transferred both *Hepseropetes jamesi* and *H. blacki* (both Emry and Korth, 2007) to *Sciurion*, Skwara 1986, based on additional specimens of both of these species from Saskatchewan; this allocation is followed here.

Sciurion jamesi (Emry and Korth, 2007)
Figure 2C, D

Hepseropetes jamesi Korth and Emry, 2007

Referred Specimen—NDGS 9590, right M3; NDGS 12674, left m3.

Measurements—M1: length = 2.04 mm; width = 2.07 mm. m3: length = 1.88 mm; width = 1.75 mm.

Discussion—The referred M3 (NDGS 9590) is heavily worn but the crenulations of enamel on the tooth are still recognizable and diagnostic of *Hesperopetes* and *Sciurion*. The lack of a metacone and metaloph on the upper molar indicates that the tooth is an M3. In size, it most closely matches that of *S. jamesi* and is distinctly larger than specimens previously referred to *S.* (=*H.*) *blacki* (Emry and Korth, 2007: table 1, fig. 2A; Korth et al., 2019a: 11-12), but smaller than the Orellan M3 from Nebraska previously identified as *Hesperopetes* sp. (Korth, 2017).

The referred m3 (NDGS 12674) is little-worn and preserves the crenulations in the talonid basin diagnostic of *Hesperopetes* and *Sciurion*. It is larger than the previously referred specimen of m3 from the lower horizons at Fitterer Ranch identified as "*Hesperopetes"* cf. "*H." blacki*. (Korth et al., 2019a: 12) but smaller than the topotypic specimens referred to *S. jamesi* (Emry and Korth, 2007: table 1). Although of similar size, the crenulations and posteriorly open trigonid distinguish it from that of the Chadronian *Hesperopetes thoringtoni*.

The m3 previously identified as "*H."* cf. *blacki* from Sampling interval 6 of Fitterer Ranch (USNM PAL 642820; Korth et al., 2019a: fig. 5D) and the specimen of m3 referred here (NDGS 12674) are larger than reported specimens of *S. blacki*, but slightly smaller than those previously referred to *S. jamesi*. Both specimens are referred here to the latter taxon.

Family Castoridae Hemprich, 1820
Genus *Agnotocastor* Stirton, 1935
Agnotocastor praetereadens Stirton, 1935
Figure 4; Table 1

Referred Specimens—NDGS 4306, left maxilla with P4-M3; NDGS 4307, right dentary fragment with p4-m1.

Description—The teeth of the referred maxilla are moderately worn. P4 is nearly square in occlusal outline, being only slightly wider than long (Table 1). The hypoflexus and mesoflexus remain open lingually and labially, respectively. The mesoflexus is narrow, nearly straight, and extends across more than half the width of the tooth. The mesoflexus is more widely open lingually and curves anteriorly near its labial end. There are three recognizable fossettes on the anterior half of the tooth and three on the posterior half.

The upper molars slightly decrease in size from M1 to M3. On all the molars the hypoflexus and mesoflexus remain open lingually and labially, respectively. On M1 and M2 the anterior parafossette and central mesofossette are nearly circular in occlusal outline and anteroposteriorly aligned. The parafossette is only slightly smaller than the mesofossette. On both M1 and M2 there is a minute metafossette in the posterolabial corner of the tooth. On M3 the metaflexus remains open posteriorly, the mesoflexus open labially, and the hypoflexus lingually. The posterior half of the M3 is narrower than the anterior half of the tooth.

The p4 and m1 of NDGS 4307 are heavily worn. The p4 is distinctly longer than the m1. The hypoflexid remains open labially on p4 and there are four fossettids, one more lingual than the others (mesoflexid), and the remaining aligned anteroposteriorly and approximately of equal size. On the m1, the hypofossettid is formed and three fossettids are arranged in a line anteroposteriorly. The paraflexid and metaflexid are nearly circular in occlusal outline while the central mesoflexid is transversely elongated.

Discussion—This species is previously reported from the Whitneyan of North and South Dakota (Stirton, 1935; Flynn and Jacobs, 2008; Korth, 2014). The

specimens reported previously from Fitterer Ranch were only from the higher part of the section, sampling intervals 5 and 6 (Fitterer Ranch Faunae B and C: Korth et al., 2019a). The specimens cited here extend the range upward to sampling interval 7 (Fitterer Ranch Fauna D).

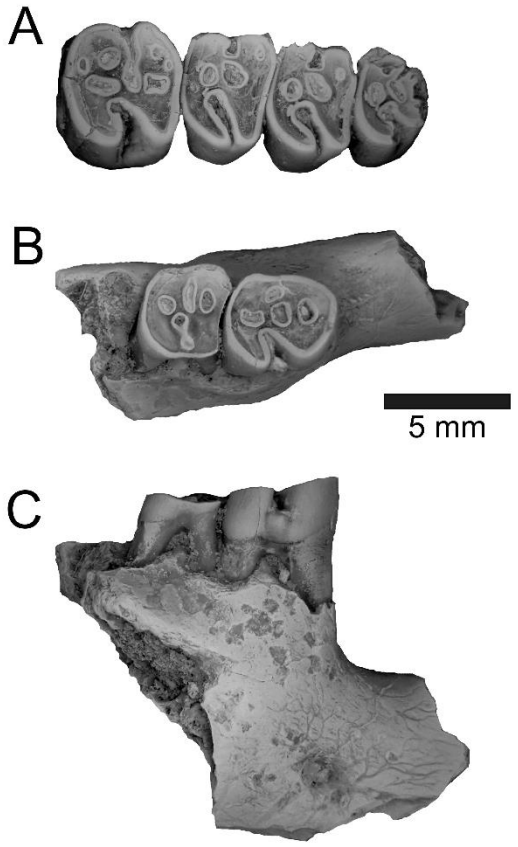

FIGURE 4. Dentition and dentary of *Agnotocastor praetereadens*. A, NDGS 4306, left P4-M3. B, C, NDGS 4307, partial dentary with right p4-m1. B, occlusal view. C, lateral view. All figures to same scale.

Family Eomyidae Winge, 1887
Genus *Adjidaumo* Hay, 1899
Adjidaumo minimus (Matthew, 1903)
Figures 5A-D; Table 2

Referred Specimens—NDGS 12643, 12658, maxilla with P4-M1; NDGS 12661, maxilla with M2-M3; NDGS 12655, 12660, dP4; NDGS 12640, 12641, 12647, 12654, 12658, 12659, 12664, 12702, 12707, P4; NDGS 12642, 12644-12646, 12648-12651, 12653, 12656, 12657, 12662, 12663, 12703, 12704, M1 or M2; NDGS 12652, 12705, 12978, M3; NDGS 12615, left dentary with i1, p4-m3; NDGS 12636, partial left dentary with m2(part)-m3; NDGS 12617, 12620, 12638, dp4; NDGS 12616, 12634, 12701, p4; NDGS 12618, 12619, 12622-12627, 12630-12633, 12701, m1 or m2; NDGS 12621, 12628, 12629, 12635, 12706, m3.

Discussion—Previously, this species was reported from sampling intervals 2 through 6 at Fitterer Ranch (Fitterer Ranch Faunae A, B, and C) and was one of the best represented rodent species in those faunae, known from over 120 specimens (Korth et al., 2019a). It is not surprising that it is as abundant at this stratigraphically higher sampling interval. The average measurements of the cheek teeth of the sample from sampling interval 7 are slightly greater (Table 2; Korth et al., 2019a: table A5), suggesting a minor increase in size of this species through the sampled stratigraphic range.

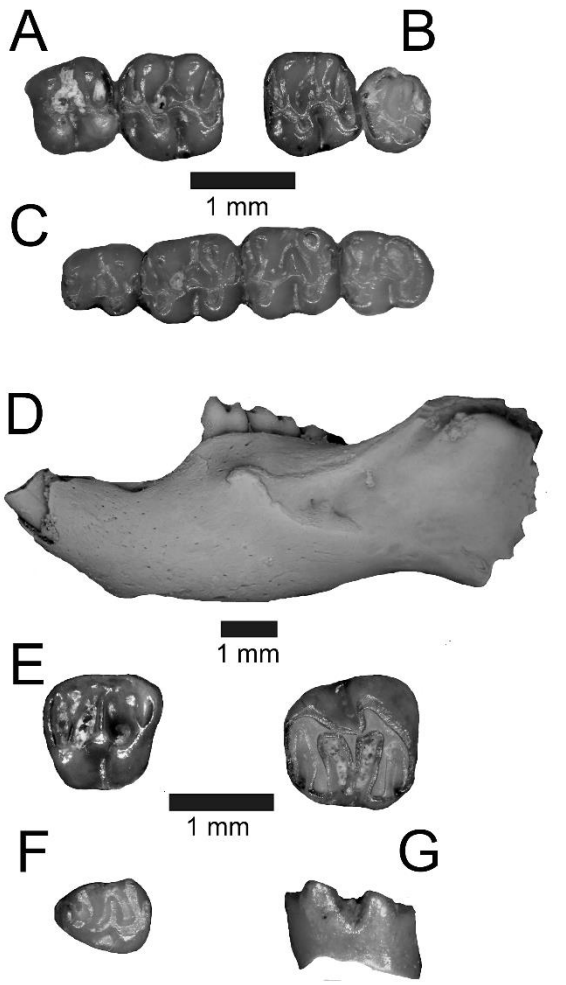

FIGURE 5. Dentition of *Adjidaumo* and *Paradjidaumo* from Upper Fitterer. A-D, *A. minutus*. A, NDGS 12658, left P4-M1. B, NDGS 12661, left M2-M3. C, D, NDGS 12615. C, occlusal view, left p4-m3. D, lateral view of dentary. E-G, *P. trilophus*. E, NDGS 12667, right P4. F, NDGS 12623, left dp4. G-H, NDGS 12672, right m1 or m2. G, occlusal view. H, lingual view. A-C and E-G to same scale (above and below); D to different scale (center).

TABLE 2. Dental measurements of *Adjidaumo minimus* from Fitterer Ranch Fauna D, Fitterer Ranch, North Dakota. Measurements in mm. Abbreviations: **CV**, coefficient of variation; **L**, length; **M**, mean; **Max**, maximum measurement; **Min**, minimum measurement; **N**, number of specimens; **SD**, standard deviation; **W**, width; *****, M1/m1 or M2/m2.

Adjidaumo minimus

	dP4L	dP4W	P4L	P4W	M1L*	M1W*	M2L	M2W	M3L	M3W
N	2	2	10	8	17	15	3	3	4	4
M	0.59	0.63	0.81	0.88	0.89	0.98	0.90	0.98	0.66	0.81
Min	0.53	0.58	0.72	0.81	0.75	0.89	0.86	0.94	0.63	0.76
Max	0.65	0.68	0.92	1.03	0.99	1.10	0.94	1.02	0.70	0.85
SD			0.07	0.08	0.06	0.06	0.04	0.04	0.03	0.04
CV			8.30	9.01	7.09	6.18	4.47	4.08	4.51	4.81

	dp4L	dp4W	p4L	p4W	m1L*	m1W*	m2L	m2W	m3L	m3W	m1-m3L
N	3	3	4	5	9	12	1	1	8	7	1
M	0.79	0.58	0.73	0.73	0.92	0.90	0.87	0.90	0.87	0.83	3.74
Min	0.74	0.51	0.67	0.63	0.86	0.83			0.79	0.76	
Max	0.85	0.68	0.80	0.81	1.00	0.96			0.94	0.89	
SD			0.05	0.08	0.05	0.04			0.05	0.06	
CV			7.39	10.33	5.33	4.17			5.70	6.74	

Genus *Paradjidaumo* Burke, 1934
Paradjidaumo trilophus (Cope, 1873a)
Figures 5E-G; Table 3

Referred Specimens—NDGS 12667, left P4; NDGS 12623, 12624, dp4; NDGS 12668-12672, 12700, m1 or m2.

Discussion—*Paradjidaumo trilophus* was previously reported from sampling intervals 2 through 6 at Fitterer Ranch (Fitterer Ranch Faunae A, B, and C). The material referred here from sampling interval 7 does not vary in morphology from that previously reported. It was noted that the measurements of the cheek teeth from Fitterer Ranch average slightly smaller than those of samples of *P. trilophus* reported from other localities (Korth et al., 2019a: tables A8, A9). This is also true of the sample from the highest level at Fitterer Ranch (Table 3). The crown-height index for m1 or m2 of the six measurable specimens of *P. trilophus* from sampling interval 7 averages 0.28 (range 0.22-0.33), lower than the average value calculated for specimens from the stratigraphically lower sampling intervals (average = 0.35), but well within the observed range of variation (0.21-0.47; Korth et al., 2019a: 20).

TABLE 3. Dental measurements of *Paradjidaumo trilophus* from Fitterer Ranch Fauna D, Fitterer Ranch, North Dakota. Measurements in mm (except ht/W). Abbreviations: **ht**, lingual crown-height; **L**, length; **W**, width; *****, m1 or m2.

Paradjidaumo trilophus

NDGS#	dp4L	dp4W	m1L*	m1W*	ht	ht/W
12623	0.94	0.75				
12624	1.08	0.83				
12668			1.26	1.23	0.28	0.23
12669			1.14	1.25		
12670			1.19	1.28	0.38	0.30
12671			1.27	1.26	0.28	0.22
12672			1.33	1.40	0.46	0.33
12700			1.30	1.34	0.42	0.31
Mean	1.01	0.79	1.25	1.29	0.36	0.28

	P4L	P4W
12667	1.18	1.16

Family Heliscomyidae Korth et al., 1991
Genus *Heliscomys* Cope, 1873a
Heliscomys borealis Korth et al., 2019a
Figure 6A; Table 4

Referred Specimens—NDGS 12694, left M1 (partial); NDGS 12695, left M1.

Discussion—The two M1s referred here bear the continuous lingual cingulum with a distinct protoconule characteristic of *Heliscomys* (Korth, 1995) and are equivalent in size to *H. borealis*, being larger than *H. senex* but smaller than the *H. cf. medius* that were previously reported from the lower sampling intervals at Fitterer Ranch (Table 4; Korth et al., 2019a: table A12). Previously, this species was reported from sampling intervals 2, 4, and 6 at Fitterer Ranch (Fitterer Ranch Faunae A, B, and C).

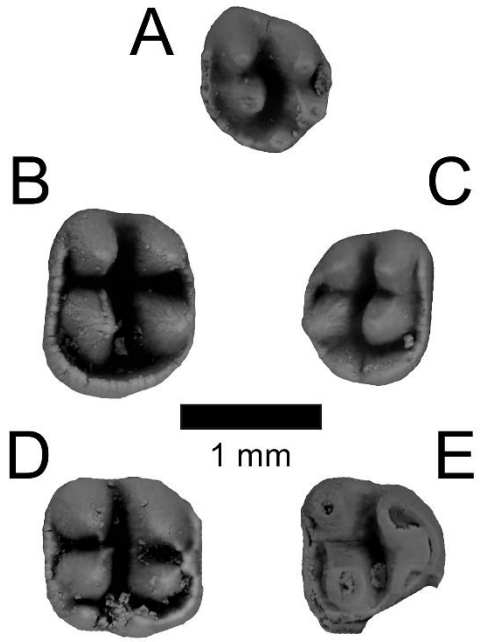

FIGURE 6. Molars of geomyoids from Upper Fitterer. A, *Heliscomys borealis*. NDGS 12695, left P4. B-F, *Kirkomys* sp. B, NDGS 12692, left M2. C, NDGS 12693, right M3. D, NDGS 12698, right m1or m2. E, NDGS 12697, left m3 (partial). All figures to same scale.

Family Florentiamyidae Wood, 1936
Genus *Kirkomys* Wahlert, 1984
Kirkomys sp.
Figures 6B-E; Table 4

Referred Specimens—NDGS 12692, left M2; NDGS 12693, right M3; NDGS 12696, 12698, 12699, m1 or m2; NDGS 12697, left m3 (partial).

Description—The M2 (NDGS 12692) is slightly wider than long and has four major cusps of approximately equal size (paracone, metacone, protocone, hypocone) arranged in two transverse rows (Figure 6B). The anterior cingulum originates along the anterior margin of the tooth, even with the apex of the paracone, extends lingually to the anterolingual corner of the tooth where it turns posteriorly, extends along the entire length of the tooth, then turns labially along the posterior margin of the tooth where it fuses with the apex of the hypocone. There is also a shorter portion of the posterior cingulum that runs from the posterolabial corner of the protocone to the apex of the metacone. There is no indication of any stylar cusps along the lingual cingulum.

The M3 (NDGS 12693) is slightly wider than long. The major cups are typically aligned in two transverse rows (Figure 6C). The labial cusps (paracone, metacone) are slightly smaller than the more lingual cusps (protocone, hypocone). Deep, distinct valleys separate the protoloph cusps from the metaloph cusps (transversely) and the lingual cusps from the labial cusps. The anterior cingulum starts along the anterior margin of the tooth even with the paracone, extends to the lingual margin of the tooth, where it wraps around the anterolingual corner and continues along the lingual margin, then extends around the posterolingual corner and runs along the posterior margin of the tooth, ultimately connecting with the apex of the metacone. Along the lingual margin are a weakly developed protostyle and hypostyle, both of which are transversely compressed with a narrow, shallow valley separating them.

The two referred m1 or m2s are of comparable size to the referred upper molars (Table 4). One, NDGS 12696, is heavily worn, whereas the others are little to moderately worn. All have the typical four-cusped pattern of geomyoids. The crown height is low (ht/W = 0.31–0.33). The metalophid cusps (metaconid, protoconid) are closer to one another than the hypolophid cusps (entoconid, hypoconid). The anterior cingulid originates at the base of the crown anterior to the metaconid, runs along the anterior margin of the tooth and wraps around the anterolabial corner of the tooth, extending for slightly more than half the length of the tooth, ending in a small, distinct protostylid. A distinct valley separates the metalophid and hypolophid cusps and extends to the labial margin of the tooth. There is a ridge that runs anterolabially from the metaconid and anterolingually from the protoconid that joins the anterior cingulid between the two cusps, forming a V-shape. There is a distinct, isolated hypostylid at the posterolabial corner of the tooth. The entoconid and hypoconid are conical and of equivalent size. A low loph from the apex of both cusps, runs anterolabially from the entoconid and anterolingually

from the hypoconid along the anterior slopes of the cusps. The posterior cingulid is near the base of the crown and extends from a point even with the apex of the hypoconid to a point even with the apex of the entoconid.

The referred m3 (NDGS 12697) is partially broken at the posterolabial corner (Figure 6E). A distinct anterior cingulid runs along the entire border of the. The anterior metaconid and protoconid are similar in size. A low ridge (protolophid) extends from the metaconid to the protoconid but is very low and bows only slightly anteriorly. The entoconid and hypoconid are smaller than the cusps of the metalophid and are positioned more closely together. Although any labial cingulum is broken away, a distinct arched posterior cingulum runs from the posterolingual corner of the hypoconid to the posterolingual corner of the entoconid. The central transverse valley between the metalophid and hypolophid is deeper than the anteroposterior valley separating the lingual and labial cusps.

Discussion—The specimens referred here to *Kirkomys* are similar in size to those previously referred to *Kirkomys* sp. from Fitterer Ranch (Korth et al., 2019a: 24) and smaller than those referred to other species of the genus (Wood, 1937: 216; Black, 1961: 6; Wahlert, 1984: table 1; Korth and Branciforte, 2007: table 5). Previously, *Kirkomys* sp. was recognized only from sampling levels 4 and 5 at Fitterer Ranch (Fitterer Ranch Fauna B: Korth et al., 2019a); elsewhere this genus is limited to the Whitneyan (Flynn et al., 2008).

Family Cricetidae Fischer de Waldheim, 1817
Eumys Leidy, 1856
Eumys brachyodus Wood, 1937
Figure 7A; Table 5

Referred Specimens—NDGS 4332, 4344, palates with left and right M1-M3; NDGS 4317, 12683, maxilla with M1-M3; NDGS 12678, 12679, 12688, M1; NDGS 12680, M2; NDGS 4316, 12681, 12682, M3; NDGS 4313, 4321, 4327, 4328, 4330, 4338, dentary with i1, m1-m3; NDGS 2596, 2620, 4311, 4326, 4329, 4333, 4336, 4337, 4341, 4342, dentary with m1-m3; NDGS 4318, 4320, dentary with i1, m1-m2; NDGS 4312, 4322, dentary with m1-m2; NDGS 2595, 4309, 4310, 4319, 4339, 4343, dentary with m2-m3; NDGS 4324, partial dentary with i1, m1; NDGS 4313, dentary with i1, m2; NDGS 4323, dentary with i1, m3; NDGS 4335, 12685, m1; NDGS 12686, m2; NDGS 4340, 12684, 12687, m3.

Discussion—*Eumys brachyodus* is the best represented rodent species from Fitterer Ranch and was previously reported from all sampling intervals, including level 7 (Korth et al., 2019a). The sample from level 7 does not differ in size or morphology from the earlier reported material from the lower sampling intervals (Table 5; Korth et al., 2019a: tables A13, A14). All previously reported occurrences of *E. brachyodus* are limited to the Whitneyan (Wood, 1937; Korth, 1994; Lindsay, 2008).

TABLE 4. Dental measurements of *Heliscomys* and *Kirkomys* from Fitterer Ranch Fauna D, Fitterer Ranch, North Dakota. Measurements in mm. Abbreviations: **ht**, lingual crown-height; **L**, length; **W**, width; –, tooth broken (unmeasurable); *****, m1 or m2.

Heliscomys borealis

NDGS #	M1L	M1W
12694	–	1.12
12695	0.86	1.03

Kirkomys sp.

NDGS #	M2L	M2W	M3L	M3W		
12692	1.01	1.25				
12693			0.86	1.06		
NDGS #	**m1L***	**m1W***	**ht**	**ht/W**	**m3L**	**m3W**
12696	1.09	1.00	0.31	0.31		
12697					0.95	1.00
12698	1.08	1.11	0.37	0.33		
12699	1.03	0.91	0.28	0.31		
Mean	1.07	1.01	0.32	0.32	0.95	1.00

Genus *Scottimus* Wood, 1937
Scottimus kellamorum Black, 1961
Figure 7B; Table 6

Referred Specimens—NDGS 12677, left M1; NDGS 12689, partial left maxilla with M2-M3; NDGS 12690, 12691, M2.

Description—The referred M1 (NDGS 12677) is heavily worn so no details of the occlusal surface are preserved but it is assigned here due to its compatible size with the other specimens from Fitterer Ranch as well as from other localities (Black, 1961: 6; Korth, 2010: table 3). The length to width ratio of M1 for the specimen (L/W = 1.52) is well within the range known for the species.

M2 is relatively narrow; the length averaging 1.24 times the width. The anterior cingulum extends the entire width of the anterior edge of the tooth and wraps slightly around the anterolingual corner. The connection of the paracone and protocone to the anterior cingulum is ‘V-shaped.’ On one specimen (NDGS 12689), both branches reach the anterior cingulum, whereas on the remaining specimens there is a short loph at the apex of

TABLE 5. Dental measurements of *Eumys brachyodus* from Fitterer Ranch Fauna D, Fitterer Ranch, North Dakota. Measurements in mm. Abbreviations: **CV**, coefficient of variation; **L**, length; **M**, mean; **Max**, maximum measurement; **Min**, minimum measurement; **N**, number of specimens; **SD**, standard deviation; **W**, width.

Eumys brachyodus											
	M1L	**M1W**	**M2L**	**M2W**	**M3L**	**M3W**	**M1-M3**				
N	8	8	7	7	9	9	6				
M	3.09	2.07	2.11	2.01	1.76	1.91	7.19				
Min	2.79	1.88	1.95	1.85	1.58	1.77	6.85				
Max	3.38	2.28	2.33	2.22	1.89	2.03	7.50				
SD	0.21	0.16	0.15	0.16	0.09	0.08	0.26				
CV	6.92	7.70	6.96	7.89	4.86	4.21	3.63				
	m1L	**m1W**	**m2L**	**m2W**	**m3L**	**m3W**	**m1-m3**	**i1L**	**i1W**	**m1L/W**	**m1W/L**
N	22	23	26	28	23	22	11	11	11	22	22
M	2.38	1.85	2.29	2.12	2.39	2.05	7.19	2.17	1.70	1.29	0.78
Min	2.02	1.60	1.98	1.88	2.16	1.84	6.60	1.84	1.48	1.12	0.68
Max	2.81	2.02	2.60	2.39	2.71	2.28	7.97	2.56	2.04	1.47	0.89
SD	0.19	0.13	0.15	0.15	0.16	0.14	0.45	0.26	0.18	0.08	0.05
CV	7.83	6.87	6.74	6.89	6.87	7.03	6.25	12.04	10.58	5.82	5.83

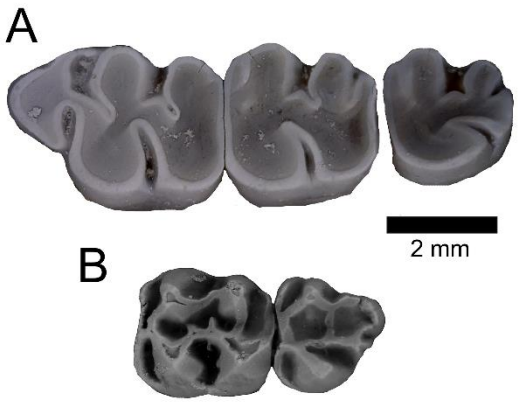

FIGURE 7. Upper dentition of *Eumys* and *Scottimus* from Upper Fitterer. A, *E. elegans*, NDGS 12683, left M1-M3. B, *S. kellamorum*, NDGS 12689, left M2-M3. All figures to same scale.

the anterior point of the V extending anteriorly to meet the anterior cingulum near its center. The protoloph is only a short spur extending labially from the protocone but not reaching the base of the paracone, but is completely lacking on NDGS 12690. The ectoloph forms an 'S-shape' from the lingual apex of the paracone to the labial apex of the metacone. On all specimens the mesoloph is only a short spur extending labially from the center of the endoloph. The metaloph bows posteriorly at its center. On NDGS 12689 it connects to the endoloph anterior to the hypocone; on the other two specimens it connects more posteriorly, with the center of the hypocone. Both the lingual cusps are crescentic in shape. The posterior cingulum bows posteriorly from the hypocone along the posterior margin of the tooth, ending at the posterolabial corner of the tooth, never reaching the metacone and separated from it by a narrow valley.

The only M3 (NDGS 12689) is approximately equal in length and width and roughly triangular in occlusal outline. The tooth is expanded labially and narrowed lingually compared to M2. The anterior half of the tooth is similar to that of M2 but the protoloph is incomplete; a well-separated short loph extends anterolingually from the paracone and anterolabially from the protocone joining the anterior. The protocone is obliquely compressed (anterolingual-posterolabial). The endoloph runs posteriorly near the center of the tooth and ending in a minute hypocone near the center of the posterior margin of the tooth. The metacone is a crescentic ridge around the posterolabial corner of the tooth, continuous with the ectoloph from the paracone. A low mesoloph connects the endoloph to the ectoloph posterior to the paracone.

Discussion—The only variation between the specimens assigned here to *Scottimus kellamorum* and those previously described is the relative proportions of the M3. M3s previously referred to this species are much longer than wide (Korth, 2010: table 3), whereas the Fitterer Ranch specimen (NDGS 12689) has essentially

TABLE 6. Measurements of upper molars of *Scottimus kellamorum* from Fitterer Ranch Fauna D, Fitterer Ranch, North Dakota. Measurements in mm. Abbreviations: **L**, length; **W**, width.

Scottimus kellamorum									
NDGS #	**M1L**	**M1W**	**M2L**	**M2W**	**M3L**	**M3W**	**L/W M1**	**W/L M1**	**L/W M2**
12677	2.49	1.64					1.52	0.66	
12689			1.81	1.53	1.45	1.44			1.18
12690			1.70	1.31					1.30
12691			1.72	1.4					1.23
Mean	2.49	1.64	1.74	1.41	1.45	1.44	1.52	0.66	1.24

equal width and length measurements (Table 6). This may not be a major difference because of the extremely limited sample of M3 known for this species.

This species was not reported previously from any of the lower sampling intervals at Fitterer Ranch at (Korth et al., 2019a). Elsewhere, the holotype of *S. kellamorum* is known from Sixty-Six Mountain, Wyoming (Whitneyan to early Arikareean [Black, 1961; Lindsay, 2008]) and from the Whitneyan Blue Ash local fauna in southwestern South Dakota (Korth, 2010).

CONCLUSIONS

The rodent fauna described herein is designated as Fitterer Ranch Fauna D, the youngest of the four assemblages described to date from the Brule Formation at the Fitterer Ranch paleontological locality. It is approximately equivalent stratigraphically with the nearby Obritsch Ranch Fauna B (Figure 1). Of the ten rodent species here reported from this new fauna, seven were previously reported from at least one of the older levels at Fitterer Ranch (Figure 8). Another species, *Sciurion* (=*Hesperopetes*) *jamesi*, was not previously reported from Fitterer Ranch (Korth et al., 2019a) but a single specimen had been referred to *S.* (=*H.*) *blacki* from Fitterer Ranch Fauna C; the two specimens described in this study are here referred to *S.* (=*H.*) *jamesi*, establishing its presence. The final two species, *Disallomys* sp., cf. *D. storeri*, and *Scottimus kellamorum*, were previously unsampled from Fitterer Ranch. Elsewhere, *D.* cf. *storeri* is known from a single Whitneyan fauna in South Dakota (Tedrow and Korth, 1997) and *S. kellamorum* is known from Whitneyan and early Arikareean faunae in South Dakota and Wyoming (Black, 1961; Lindsay, 2008; Korth, 2010). However, the rarity of these two taxa in this study (three and four specimens, respectively) leaves open the possibility that their perceived absence within the three older faunae at Fitterer Ranch and from Obritsch Ranch Fauna B could be an artifact of sampling.

Eleven of the eighteen rodent species previously identified from the three older faunae at Fitterer Ranch are absent from Fitterer Ranch Fauna D (Figure 8). Of those taxa, six are known from fewer than five specimens (predominantly isolated teeth), suggesting that increased sampling may be required to find these taxa if they were present within Fitterer Ranch Fauna D (*?Microparamys* sp., *Cedromus wardi*, *Eumys lammersi*, *Sciurion blacki*, *Oligotheriomys magnus*, and *Heliscomys medius*). Alternatively, five of those species are better represented within the lower sampling intervals, providing more confidence that their absence from this study is real (*Heliscomys senex*, *Willeumys viduus*, *Prosciurus hogansoni*, *Adjidaumo minutus*, and *Ischyromys typus*). Size does not seem to be an important sampling factor in this study given that partial jaws with teeth of some larger taxa, such as the castorid *Agnotocastor*, were collected in this study. Thus, the absence of other large-bodied rodent taxa in this study (e.g., *Ischyromys*, *Prosciurus*) could represent a real signal.

TABLE 7. Relative diversity of rodent clades between Fitterer Ranch Fauna D (FRD) and Obritsch Ranch Fauna B (ORB), Brule Formation, Stark County, North Dakota.

	Fitterer Ranch Fauna D		**Obritsch Ranch Fauna B**	
Clade	**Taxa (%)**	**Specimens (%)**	**Taxa**	**Specimens (%)**
Sciuroidea	3 (30%)	7 (5%)	4 (31%)	15 (12%)
Eomyidae	2 (20%)	67 (50%)	2 (15%)	44 (36%)
Cricetidae	2 (20%)	50 (37%)	2 (15%)	22 (18%)
Heliscomyidae	1 (10%)	2 (1%)	2 (15%)	39 (32%)
Castoridae	1 (10%)	2 (1%)	1 (8%)	1 (1%)
Florentiamyidae	1 (10%)	6 (4%)	0 (0%)	0 (0%)
Heteromyidae	0 (0%)	0 (0%)	1 (8%)	1 (1%)
Ischyromyidae	0 (0%)	0 (0%)	1 (8%)	1 (1%)

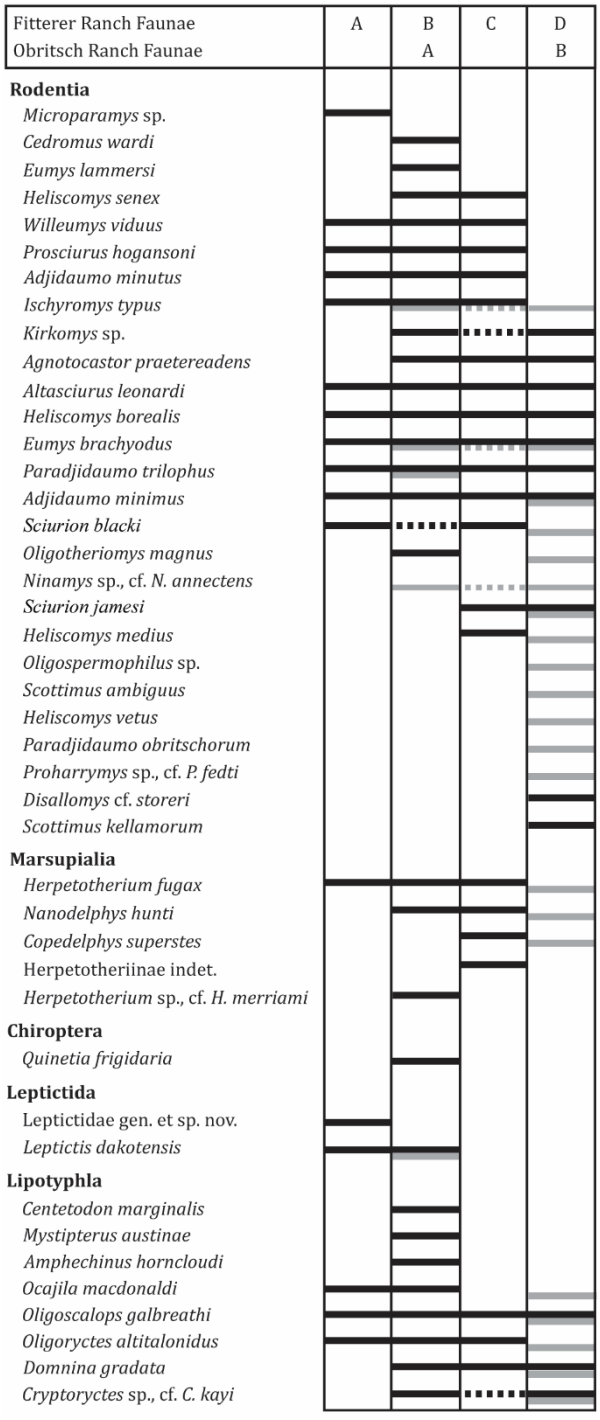

FIGURE 8. Biostratigraphic distribution of micromammal taxa within the five faunae of Fitterer Ranch and Obritsch Ranch. Oldest to youngest left to right. Modified from Korth et al. (2023: fig. 10) with new data added from this study. See Korth et al. (2021) for definitions of each fauna. Black occurrences for Fitterer Ranch, gray for Obritsch Ranch.

At the nearby Obritsch Ranch locality, fossils assigned to Obritsch Ranch Fauna B were collected from a sandstone channel within the upper portion of the '1st banded layer' of Skinner (1951), along with a few specimens recovered from the overlying pink siltstone bed (Korth et al., 2019b: fig. 14). This is a similar, but slightly lower, stratigraphic position as the bed sampled in this study at Fitterer Ranch (Figure 1). Comparison of these two faunae reveals that they are broadly similar at higher taxonomic levels (Table 7), although there are more marked differences at the species level (Figure 8). *Eumys brachyodus* and *Adjidaumo minimus* make up the majority of rodent specimens recovered from both faunae (65% at Obritsch Ranch and 77% at Fitterer Ranch) but the only other taxon present in both faunae is the sciurid *H. jamesi*. The eomyid *Paradjidaumo* and the cricetid *Scottimus* are present in both, with *P. trilophus* and *S. kellamorum* present at Fitterer Ranch and *P. obritschorum* and *S. ambiguus* present at Obritsch Ranch. The heliscomyid *Heliscomys* is also present in both faunae, represented by a single species (*H. borealis*) at Fitterer Ranch and two species (*H. medius* and *H. vetus*) at Obritsch Ranch. Sciuroids (Aplodontidae + Sciuridae) make up approximately 30% of the documented rodent diversity in each fauna (Table 7), with two aplodontids and one sciurid present at Fitterer Ranch (*Altasciurus leonardi*, *Disallomys* cf. *storeri*, and *Sciurion jamesi*) and one aplodontid and three sciurids present at Obritsch Ranch (*Nanomys* cf. *annectens*, *Sciurion blacki*, *S. jamesi*, and *Oligospermophilus* sp.).

The clearest differences between these two assemblages are the presence of the ischyromyid *Ischyromys typus* and the heteromyid *Proharrymys* cf. *feldti* at Obritsch Ranch and the presence of the florentiamyid *Kirkomys* sp. at Fitterer Ranch, though all three taxa are known from few specimens (1, 1, and 6, respectively). Looking at total numbers of specimens of each rodent group recovered from each fauna (Table 7), the largest discrepancy is seen in the heliscomyids, which comprise nearly one-third of all specimens recovered from Obritsch Ranch Fauna B, while only two specimens (~1%) were recovered from Fitterer Ranch Fauna D. The small number of heliscomyids from the latter fauna also contrasts with Fitterer Ranch Fauna C, where heliscomyids compose 15 percent (88 out of 591) of recovered specimens. Alternatively, the Whitneyan Blue Ash and Cedar Pass local faunae from South Dakota also produce comparatively few heliscomyid specimens (0 and 4, respectively: Korth, 2007, 2014; Korth et al., 2019b), though aqueous screen washing was not conducted at either of those localities.

Overall, the observed differences between Fitterer Ranch Fauna D and Obritsch Ranch Fauna B are interesting given that the two localities are only three

miles apart, are situated in a similar stratigraphic position within the Brule Formation, were sampled using similar methodologies (i.e., aqueous screen washing), and are known from a similar number of specimens (123 versus 134). It is possible that differences result from the fact that these faunae were recovered from rocks deposited within different depositional environments, with most specimens from Obritsch Ranch Fauna B recovered from a channel sandstone and specimens from Fitterer Ranch Fauna D recovered from deposits on a flood plain with evidence of paleosol development. It is also possible that Fitterer Ranch Fauna D is slightly younger than Obritsch Ranch Fauna B and some of the differences noted reflect temporal changes in the rodent fauna of the northern Great Plains Region through the Whitneyan NALMA.

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REFERENCES

Bell, S.D., T. Meyer, and J.E. Storer. 2023. New species of *Sciurion* and *Hesperopetes* (Mammalia, Rodentia, Sciuridae) from Oligocene faunas of the Cypress Hills Formation, Saskatchewan. Paludicola, 14:87–94.

Black, C.C. 1961. New rodents from the early Miocene deposits of Sixty-Six Mountain, Wyoming. Breviora, 146:1-7.

Bowdich, T.E. 1821. An Analysis of the Natural Classifications of Mammalia for the Use of Students and Travelers. J. Smith, Paris, 115 pp.

Brandt, J.F. 1855. Beitrage zur nahern Kenntniss der Säugethiere Russland's. Kaiserlichen Akademie der Wissenschaften, Saint Petersburg, Mémoires Mathématiques, Physiques et Naturelles, 7:1-365.

Burke, J.J. 1934. New Duchesne River rodents and a preliminary survey of the Adjidaumidae. Annals of Carnegie Museum, 23:391-398.

Cope, E.D. 1873. Synopsis of new Vertebrata form the Tertiary of Colorado, obtained during the summer of 1873. Washington Government Printing Office, October 1873, pp. 1-19.

Croft, D.A., T. Kaye, and L. Panko. 2004. A new method for finding small vertebrate fossils: ultraviolet light at night. Palaeontology, 47:795-800.

Czaplewski, N.J., J.J. Person, C.A. Boyd, and R.J. Emry. 2019. A new species of bat (Chiroptera: Vespertilionidae) from the early Oligocene global cooling period, Brule Formation, North Dakota, USA. Palaeovertebrata 42:e2.

Emry, R.J., and W.W. Korth. 2007. A new genus of squirrel (Rodentia, Sciuridae) from the mid-Cenozoic of North America. Journal of Vertebrate Paleontology, 27:693-698.

Fischer de Waldheim, G. 1817. Adversaria zoological. Mèmoires del la Société Impérial des Naturalistes du Moscou, 5:357–428.

Flynn, L.J., and L.L. Jacobs. 2008. Castoridae. Pp. 391-405, in Evolution of Tertiary Mammals of North America, Volume 2: Small Mammals, Xenarthrans, and Marine Mammals. C.M. Janis, C.R. Gunnell and M.D. Uhen (eds.) Cambridge University Press, Cambridge.

Flynn, L.J., E.H. Lindsay, and R.A. Martin. 2008. Geomorpha. Pp. 428-455, in Evolution of Tertiary Mammals of North America, Volume 2: Small Mammals, Xenarthrans, and Marine Mammals. C.M. Janis, C.R. Gunnell, and M.D. Uhen (eds.) Cambridge University Press, Cambridge.

Hay, O.P. 1899. Notes on the nomenclature of some North American fossil vertebrates. Science, 10:253-254.

Hemprich, W. 1820. Grundriss der Naturgeschichte für hohere Lehranstalten Entworfen von Dr. W. Hemphrich. August Rucher, Berlin; Friedrich Volke, Vienna.

Korth, W.W. 1994. The Tertiary Record of Rodents in North America. Topics in Geobiology, Plenum Press, New York. Volume 12, 319 pp.

Korth, W.W. 2007. Mammals from the Blue Ash local fauna (late Oligocene), South Dakota. Rodentia, Part 1: Families Eutypomyidae, Eomyidae, Heliscomyidae, and *Zetamys*. Paludicola, 6:31-40.

Korth, W.W. 2009. Mammals from the Blue Ash local fauna (late Oligocene), South Dakota. Rodentia, Part 4: Family Aplodontidae. Paludicola, 7:89-106.

Korth, W.W. 2010. Mammals from the Blue Ash local fauna (late Oligocene), South Dakota. Rodentia, Part 5: Family Cricetidae. Paludicola, 7:117-136.

Korth, W.W. 2014. Rodents (Mammalia) from the Whitneyan (middle Oligocene) Cedar Pass fauna of South Dakota. Annals of Carnegie Museum, 82:373-397.

Korth, W.W., and C. Branciforte. 2007. Geomyoid rodents (Mammalia) from the Ridgeview local fauna, early-early Arikareean (late Oligocene) of western Nebraska. Annals of Carnegie Museum, 76:177-201.

Korth, W.W. and A.R. Tabrum. 2017. A unique rodent fauna from the Whitneyan (middle Oligocene) of southwestern Montana. Annals of Carnegie Museum, 84: 319-340.

Korth, W.W., J.H. Wahlert, and R.J. Emry. 1991. A new species of *Heliscomys* and recognition of the family Heliscomyidae (Geomyoidea, Rodentia). Journal of Vertebrate Paleontology, 11:247–256.

Korth, W.W., R.J. Emry, C.A. Boyd, and J.J. Person. 2019a. Rodents (Mammalia) form Fitterer Ranch, Brule Formation (Oligocene), North Dakota. Smithsonian Contributions to Paleobiology, 103:1-45.

Korth, W.W., C.A. Boyd, and J.J. Person. 2019b. Whitneyan (middle Oligocene) rodents from Obritsch Ranch (Stark County, North Dakota) and a review of Whitneyan rodent fossil record.

Korth, W.W., C.A. Boyd, R.J. Emry, and J.J. Person. 2021. Marsupials (Mammalia, Metatheria) from Brule Formation (Oligocene), North Dakota. Journal of Paleontology, 95:193-204.

Korth, W.W., C.A. Boyd, J.J. Person, and D.K. Anderson. 2023. Additional small mammals from the Oligocene (late Orellan-Whitneyan) of southwestern North Dakota. Paludicola, 14:57-74.

Leidy, J. 1856. Notices of remains of extinct Mammalia discovered by Dr. F.V. Hayden in Nebraska Territory. Proceedings of the Academy of Natural Sciences of Philadelphia, 8:88–90.

Lindsay, E.H. 2008. Cricetidae. Pp. 456-479, in Evolution of Tertiary Mammals of North America, Volume 2: Small Mammals, Xenarthrans, and Marine Mammals. C.M. Janis, C.R. Gunnell and M.D. Uhen (eds.) Cambridge University Press, Cambridge.

Matthew, W.D. 1903. The fauna of the *Titanotherium* Beds at Pipestone Springs, Montana. Bulletin of the American Museum of Natural History, 16:1-19.

Prothero, D.R., 1996. Magnetic stratigraphy of the White River Group in the High Plains, *in* Prothero, D.R., and Emry, R.J., eds., The Terrestrial Eocene-Oligocene Transition in North America. Cambridge University Press, New York, p. 262-277.

Prothero, D.R., and R.J. Emry. 2004. The Chadronian, Orellan, and Whitneyan North American Land Mammal Ages; pp. 156-168 in M.O. Woodburne (ed.), Late Cretaceous and Cenozoic Mammals of North America. Columbia University Press, New York.

Skinner, M.F. 1951. The Oligocene of western North Dakota, *in* Bump, J.D., ed., Society of Vertebrate Paleontology Guidebook, 5th Annual Field Conference, Western South Dakota, August – September 1951. p. 51-58.

Skwara, T.A. 1986. New "flying sqiurrel" (Rodentia, Sciuridae) from the early Miocene of southwestern Saskatchewan. Journal of Vertebrate Paleontology, 6:290-294.

Stirton, R.A. 1935. A review of the Tertiary beavers. University of California Publications in the Geological Sciences, 23:391–458.

Tedrow, A.R., and W.W. Korth. 1997. New aplodontid rodents (Mammalia) form the Oligocene (Orellan and Whitneyan) of Slim Buttes, South Dakota. Paludicola, 1:80-90.

Wahlert, J.H. 1984. *Kirkomys*, a new florentiamyid (Rodentia, Geomyoidea) from the Whitneyan of Sioux County, Nebraska. American Museum Novitates, 27893:1-8.

Wilson, R.W. 1949. On some White River fossil rodents. Carnegie Institute of Washington Publication, 584:27–50.

Winge, A.H. 1887. Jordfunde og nulevende Gnavere (Rodentia) fra Lagoa, Minas Geraes, Brasilien. Universitat Museuo Lundil, Copenhagen, 1:1-300.

Wood, A.E. 1936. A new subfamily of heteromyid rodents form the Miocene of western United States. American Journal of Science, 31:41-49.

Wood, A.E. 1937. The mammalian fauna of the White River Oligocene, Part 2, Rodentia. Transactions of the American Philosophical Society, 28:155–269.

Wood, A.E. and R.W. Wilson. 1936. A suggested nomenclature for the cusps of the cheek teeth of rodents. Journal of Paleontology, 10:388-391.