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Caves, arvicoline rodents, and chronologic resolution

Christopher N. Jass

ABSTRACT

Fossiliferous sedimentary deposits provide opportunities for paleontologists to explore detailed questions about the past history of individual species and assemblages. Caves often retain data sets that allow for detailed investigations into site chronology, paleoecology, and local faunal history. Re-evaluation of the arvicoline rodent assemblage from Smith Creek Cave, Nevada, resulted in a taxonomic data set that potentially conflicts with the previously published site chronology. Specifically, identification of previously unreported taxa included possible records of *Microtus meadensis* and *M. paroperarius*. Also identified were 4-triangle morphotypes of *Lemmiscus curtatus*. Smith Creek Cave is one of few known localities to preserve a 4-triangle morphotype of *L. curtatus*. The possible occurrences of *M. meadensis* and *M. paroperarius* in one of the lowest sedimentary horizons in Smith Creek Cave (the reddish-pink silt zone) are particularly significant given the known chronologic distribution of these taxa (between 820 Ka and 146.02 ± 2.584 to 153.7 ± 6.4 Ka). A revised age estimate for the reddish-pink silt zone, based on known chronologic ranges of *M. meadensis* and *M. paroperarius*, would be markedly different than the published radiocarbon age for those sediments (28,650 ± 760 ^{14}C yr BP). The chronologic quandary between age estimates re-emphasizes the complex nature of paleontological and archaeological accumulations in cave deposits.

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INTRODUCTION

Caves were recognized as potential sources of paleontological data as early as 1821 when William Buckland reported fossil remains from cave deposits in Kirkdale, England (Buckland 1821). Since that time, numerous research projects carried out in fossiliferous cave deposits have improved our understanding of vertebrate history (Lundelius 2006). Factors contributing to the utility of caves as paleontological data sources include the preservation of large sample sizes (e.g., Bar-

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nosky and Bell 2003), preservation of uniquely fossilized materials (e.g., dung deposits; Martin et al. 1961), and the preservation of independent paleoecological data sets (e.g., packrat middens, palynological data, vertebrate fossils, isotopic data derived from speleothems). This combination of features suggests that there is great potential for researchers working in cave deposits to utilize independent data sets for the development of site chronologies and for the interpretation of past biotic conditions. While congruence in such data sets would produce ideal scientific results, the reality is that independent data sets are sometimes found to be inconsistent with each other.

Cathedral Cave, Nevada, preserved a diverse arvicoline rodent assemblage (i.e., voles, lemmings, and muskrats) that was incongruent with late Pleistocene age estimates based on uranium-series dates (Bell 1995; Bell and Barnosky 2000; Bell et al. 2004a; Jass 2005). These conflicting data sets led to new investigations at Cathedral Cave that incorporated fine-scale (5 cm levels) excavation, uranium-series analysis, and paleomagnetic analysis in relation to the occurrence of arvicolines throughout the excavated sedimentary levels (Jass 2007; Jass and Bell in press). Because of the close geographic proximity of Cathedral Cave to other Quaternary cave deposits, I wanted to determine whether a similar scenario might be recorded in other local sites.

In conjunction with research at Cathedral Cave, Nevada, I re-examined arvicoline rodent fossils collected from previous archaeological excavations conducted at Smith Creek Cave (SCC). My re-examination of the SCC arvicoline specimens yielded unexpected results, including the identification of tooth morphologies that resemble taxa not known to persist into the latest Pleistocene (e.g., *Microtus paroperarius* and *M. meadensis*). The presence of these morphologies was perplexing, given the known chronological distribution of *Microtus paroperarius* and *M. meadensis*, and the published radiocarbon chronology and sedimentary sequence of SCC. In this paper I provide a comprehensive description of the arvicoline rodent taxa from SCC, discuss the possible implications of the arvicoline fauna with respect to age control at the site, and discuss some complexities involved in resolving chronologic sequences in North American cave deposits.

Physical Setting, Background, and Chronologic Framework for Smith Creek Cave

Smith Creek Cave is a large rock shelter (~ 50 m x 18 m x 30 m) located at the mouth of Smith Creek Canyon in the northern Snake Range of eastern Nevada. Since 1925 several archaeological and paleontological excavations were conducted at SCC with the most recent field research efforts taking place in 1968, 1971, and 1974 (see summaries in Bryan 1979 and Mead et al. 1982). Publications addressing the vertebrate fauna from SCC include type descriptions of *Oreamnos harringtoni* (Stock 1936), *Spizaetus willetti* (Howard 1935), and *Teratornis incrediblis* (Howard 1952). Additional reports provide a discussion of the herpetofauna (Brattstrom 1958, 1976), a summary faunal list (Goodrich 1965), a mammalian faunal list (Miller 1979), a detailed review of the late Pleistocene/Holocene fauna known from multiple sites in Smith Creek Canyon (Mead et al. 1982), and additional records of arvicoline rodents (Mead et al. 1992; Bell and Mead 1998).

Early reports on fossils from SCC provided limited data regarding site stratigraphy or age control (see Mead et al. 1982), and the primary chronologic framework for the site was established in conjunction with the archaeological investigations of 1968, 1971, and 1974 (Bryan 1979). A complicated site stratigraphy was reported as part of these investigations, with friable sediments, human occupation, rodent burrowing, and recent human activity all contributing to the complexity of the sedimentary sequence at SCC (Bryan 1979; Miller 1979). Nineteen radiocarbon dates taken on charcoal (n = 14), wood (n = 2), pine needles (n = 1), vegetation (n = 1), and bone (n = 1), placed much of the SCC deposit within the late Pleistocene-Holocene with dates ranging from 28,650 ± 760 yr BP to 1675 ± 90 yr BP (Bryan 1979).

Arvicoline Rodents as Time Markers

Arvicoline rodents are known from the late Miocene-Recent in North America (Repenning et al. 1990). Rapid rates of reproduction known in extant arvicolines, along with a highly diversified and rapidly evolving dentition, underscore the significance of this group in late Tertiary through Quaternary biochronology. Recognition of the importance of arvicoline rodents as biochronological markers in North American terrestrial deposits began with research in the Meade Basin of Kansas (e.g., Hibbard 1944, 1949). Arvicoline biochronology advanced significantly in the 1970s and 1980s with the work of Martin (1979) and Repenning

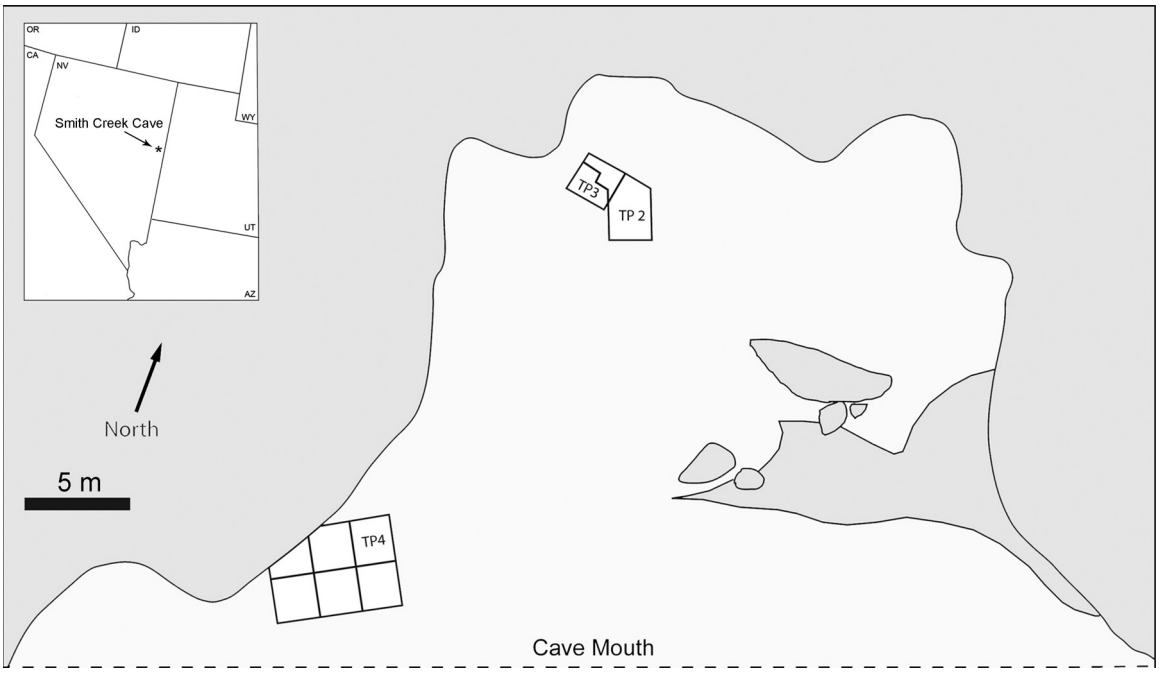

FIGURE 1. Simplified plan view map of Smith Creek Cave showing test pit areas (TP) that produced the fossils discussed in this report. Gray equals bedrock. Modified from Bryan (1979). Inset shows geographic location of Smith Creek Cave.

(1978, 1980, 1984, 1987) who developed conceptually and contextually distinct temporal divisions for the continent (Bell 2000). Ultimately, relative chronologic frameworks are subject to change with the addition of new data and/or independent dating methods, and this fluidity is reflected in recent work summarizing the chronological distribution of arvicoline rodent taxa (e.g., Bell and Barnosky 2000; Bell et al. 2004a, 2004b; Martin et al. 2008). Nonetheless, because they are known to occupy discrete time intervals (see Bell 2000, for review), the presence of unique arvicoline tooth morphologies within a sedimentary sequence can be used to bracket the age of fossiliferous deposits.

STUDY MATERIALS

I examined 296 lower first molars (m1) from arvicoline rodents collected from Smith Creek Cave. My sample was restricted to the m1s because they are often identifiable to genus or species whereas other isolated molars tend to be taxonomically less informative (Bell and Repenning 1999; Semken and Wallace 2002). With one exception (noted below), all specimens discussed here are curated at the Nevada State Museum in Carson City. Prior to this report none of the SCC arvicoline specimens housed at the Nevada State Museum were uniquely numbered or curated independently from one another, or from the other faunal remains. Therefore, I was not able to provide re-evaluations of the specific specimens or abundance data listed in previous reports (Miller 1979; Mead et al. 1982). Individual specimens presented here were assigned permanent, unique numbers preceded by the prefix “SCCAR” (= Smith Creek Cave Arvicoline Rodent). Appendix 1 summarizes specimens examined for this study.

There was some inconsistency in the labeling of bags containing faunal remains from SCC. With the aid of original field notes housed at the Nevada State Museum and published stratigraphic data (Bryan 1979), I was able to clarify the provenience of most specimens examined for this study. All but 12 of the examined specimens were associated with a single sedimentary stratum identified from test pits near the rear of the cave (TP 2 and TP 3 of Figure 1; Appendix 2).

The color of this primary bone-bearing stratum was described in a variety of manners (reddish-brown, reddish-pink, red, and pink) on both bone bag labels and in the literature (Bryan 1979; Miller 1979). Within the framework of this paper, I refer to this stratum as the ‘reddish-pink silt’. Although lacking a detailed discussion of sedimentological characteristics, Bryan’s original report (1979) clearly separates the reddish-pink silt from overly-

ing and underlying sediments on the characteristics of sediment itself and bone color. Cemented white sediments and bones exhibiting a coating of calcium carbonate occur below the reddish-pink silt (Bryan 1979). Sediments from the immediately overlying stratum are characterized by the presence of human artifacts, whereas evidence to suggest human activity during the time of deposition of the reddish-pink silt is equivocal (Bryan 1979). Bones collected from strata above the reddish-pink silt that I was able to observe in the collection of the Nevada State Museum are whitish and lack the characteristic red stain of bone from the reddish-pink silt. Bone preserved in rodent burrows that intruded into the reddish-pink silt exhibited different levels of staining, if any (Bryan 1979). There is no indication in the literature to suggest that bone was limited in distribution within the reddish-pink silt level. The relationship between sedimentary levels at the front and back of the cave remains unclear. The reddish-pink silt from the rear of the cave may stratigraphically correlate with a deposit of rubble and pink silt from near the cave mouth (Bryan 1979), although this equivalence was neither demonstrated in previous reports nor is it clearly evident from exposed trenches in the cave. However, bone was reported as being absent from lower sedimentary levels near the mouth of the cave (Miller 1979).

Given the sedimentary information presented above, it is reasonable to assume that Bryan's original interpretation of the reddish-pink silt as a discrete sedimentary level was appropriate. For my evaluation of the arvicoline rodents from SCC, I considered bags of curated bones ascribed to a red silt, reddish-pink silt, reddish-brown silt, or pink layer to be stratigraphically equivalent, as long as they could be tied to the test pits from the rear of the cave.

All arvicoline teeth presented here that were sorted from these bags retain a reddish stain and conform to Bryan's (1979) description of bone from the reddish-pink silt. The remaining specimens reported here either come from a layer of rodent dung and brown silt situated stratigraphically above the reddish-pink silt (five specimens), or were of unknown stratigraphic provenience due to limitations in associated data (seven specimens).

For strata that underlie unequivocal archaeological levels (e.g., reddish-pink silt) two radiocarbon dates are known (Bryan 1979). The first, based on bristlecone pine needles occurring in a layer near the mouth of SCC, resulted in an age of 12,600 ± 170 ^{14}C yr BP (A-1565). The second resulted in a radiocarbon age of 28,650 ± 760 ^{14}C yr BP (Tx-1639) and was based on a sample of bone collagen extracted from an unidentifiable bone fragment collected in the reddish-pink silt near the rear of the cave (Bryan 1979). I used the publicly accessible, online radiocarbon calibration program at http://www.radiocarbon.LDEO.columbia.edu/ to calibrate calendar ages for these radiocarbon dates (Fairbanks et al. 2005). Calibrated ages for the radiocarbon dates of 28,650 ± 760 ^{14}C and 12,600 ± 170 ^{14}C yr BP were 34,039 ± 799 cal yr BP and 14,627 ± 277 cal yr BP, respectively. Given the nature of the radiocarbon sample (collagen) from the reddish-pink silt and confusion surrounding the provenience of the sample, the date of 28,650 ± 760 ^{14}C yr BP provides only a rough estimate of the age of the reddish-pink silt zone (Mead et al. 1982). All other radiocarbon dates from the site are younger and most are associated with archaeological materials (Bryan 1979; Thompson 1985).

IDENTIFICATION METHODS

Taxonomic identifications of arvicoline m1s from SCC were based on comparisons with the m1s of extant and extinct arvicolines and descriptions of those taxa from the literature. Initial examination and identification of specimens was conducted using 10x magnification. Subsequent verification of the identifications was conducted under a binocular microscope at varying magnification levels.

Dental terminology discussed here and depicted in Figure 2 follows Bell and Jass (2004). The m1 of arvicolines may be rooted or unrooted depending on the taxon. All arvicoline m1s have a posterior loop, a series of enamel-bound triangles, and an anterior cap (Figure 2). Open spaces between triangles are referred to as reentrant angles and may or may not be filled with cementum depending on the taxon. Triangles are numbered sequentially from back to front, and abbreviated references to individual triangles are used in the text below (e.g., T1; see Figure 2). "Primary wings" refers to T4 and T5 whereas "secondary wings" refers to T6 and T7 (Figure 2).

On the illustrations, enamel bands are shown in white, dentine is in black, and cementum is stippled. Broken or missing portions of the teeth are depicted with a series of horizontal lines. The closure of individual triangles relative to each other or the anterior cap was categorized as being open, pinched, exhibiting incipient closure, or closed following Bell and Barnosky (2000). Open or conflu-

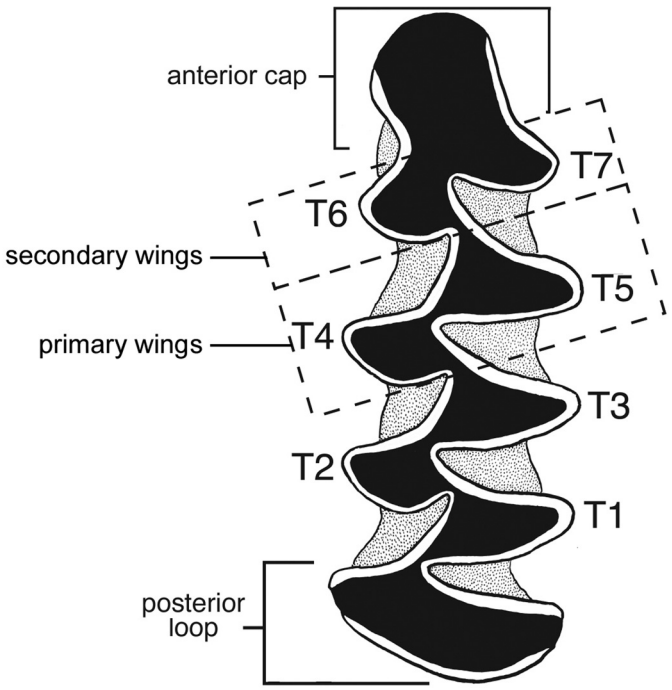

FIGURE 2. General structure and features of the lower first molar in arvicoline rodents showing position of primary and secondary wings. Individual triangles are referred to by a capital "T" and a unique number (e.g., T1). Enamel closure between T1 and T2 depicts a closed triangle state. Confluence of T6 and T7 depicts an open triangle state. Modified from Bell and Jass (2004).

ent triangles had openings that exceeded three enamel bandwidths. Pinched triangles exhibited openings between two and three enamel bandwidths. Triangles with incipient closure had openings between one and two enamel bandwidths. Closed triangles had openings of less than one bandwidth of enamel.

RESULTS

The four arvicoline rodent taxa identified from SCC include extinct (*Microtus meadensis*, *Microtus paroperarius*) and extant voles [*Microtus* sp. (not *Microtus meadensis* or *Microtus paroperarius*), *Lemmiscus curtatus*]. Both *Microtus* sp. and *Lemmiscus curtatus* are characterized in the fauna by multiple morphotypes. These include the four-triangle form of *Lemmiscus curtatus*, a morphotype that persisted only into the early Holocene (Barnosky and Bell 2003; Bell and Jass 2004). Identifying characteristics and abundance of each identified taxon are discussed below.

Two hundred thirty-nine specimens (80.7%) were identified as *Microtus* sp., making it the dominant taxon in the SCC deposit. These specimens exhibit greater labial-lingual length in T1 than T2, a character that can be used to distinguish *Microtus* from *Lemmiscus* (Barnosky and Rasmussen 1998). Specimens identified as *Microtus* sp. in this paper are characterized by the presence of at least five closed, alternating triangles, distinguishing them from both *Microtus paroperarius* and *Microtus meadensis*. Previous reports on the SCC fauna separated *Microtus* cf. *M. montanus* (Goodrich 1965; Miller 1979) and *Microtus* cf. *M. longicaudus* (Mead et al. 1982) as distinct from other specimens referred to *Microtus* sp. Given the current state of knowledge regarding identification of m1s of *Microtus* at the species level (see Bell et al. 2004a for discussion), there is no morphological basis for the identification of *Microtus* cf. *M. montanus* and *Microtus* cf. *M. longicaudus* from SCC. I consider previous reports of these taxa to be synonymous with *Microtus* sp. as reported here.

Lower first molars of *Microtus* show high levels of variation (e.g., Paulson 1961; van der Meulen 1978; Guilday 1982; Weddle and Choate 1983; Martin 1987, 1993; Harris 1988; Barnosky 1990, 1993; Pfaff 1990; Bell and Repenning 1999; Gor-

don 1999), and specimens recovered from SCC are no exception. Ten morphologic variants of *Microtus* sp. were recovered. These are a five-triangle form with well-developed secondary wings that are confluent with the anterior cap (196 specimens; Figure 3A), a five-triangle form where triangles 1 and 2 are confluent with one another (one specimen; Figure 3B), a five-triangle form where T6 is pinched from T7 and anterior cap (16 specimens; Figure 3C), a five-triangle form where T6 is pinched from T7 but T7 is closed from the anterior cap (one specimen; Figure 3D), a five-triangle form where the T6 exhibits incipient closure from T7 and anterior cap (three specimens; Figure 3E), a five-triangle form where T6 and T7 are confluent but are closed from the anterior cap (three specimens; Figure 3F), a five-triangle form where T6 and T7 are confluent but are pinched from the anterior cap (one specimen; Figure 3G), a five-triangle form where T6 and T7 are confluent but exhibit incipient closure from the anterior cap (one specimen; Figure 3H), a six-triangle form where T6 is closed from a confluent T7/anterior cap complex (15 specimens; Figure 3I), and a seven-triangle form where both secondary wings (T6 and T7) are closed (one specimen; Figure 3J). A single specimen (SCCAR-115) of the common five-triangle form has a unique morphology where T4 is bifurcated (Figure 3K). This morphology was previously noted on specimens of *Microtus pinetorum* from late Quaternary deposits in Iowa (Jans 1993; Wallace 2001). One specimen (SCCAR-203) had T5 pinched from the secondary wings/anterior cap in occlusal view, but T5 was closed in ventral view. I conservatively identified this specimen as *Microtus* sp. rather than *M. paroperarius* (see description below).

Two of the 296 specimens examined for this study (< 1%) were identified as *Microtus meadensis* and are characterized by the presence of three closed, alternating triangles (Triangles 1-3), followed by confluent primary wings (Triangles 4 and 5), which are closed from the secondary wings (Triangles 6 and 7) and anterior cap (Figure 4A). The enamel of the m1 is positively differentiated (terminology follows Martin 1987), where the leading or anterior edges of triangles retain thicker enamel than on the trailing or posterior edges. Cementum is present in the re-entrant angles. This m1 structure is similar to that found in some extant *Microtus quasiater* and *Microtus pinetorum* (Repenning 1983; Zakrzewski 1985). Previous authors described features that characterize the m1 of *Microtus meadensis* and other extant taxa with similar morphologies (Martin 1987; Harris 1988). However, the frequency of distinct m1 morphologies in these populations is undocumented.

Three of the 296 specimens (1.0%) were identified as *Microtus paroperarius*. These m1s have four closed, alternating triangles, followed by a well-developed fifth triangle that is variably confluent with the secondary wings and anterior cap (Figure 4B, C). Two of these specimens exhibit a state where the fifth triangle is pinched from the secondary wings (e.g., Figure 4B). In one specimen (SCCAR-212), the fifth triangle is broadly confluent with the secondary wings (Figure 4C). This variation is consistent with that seen in other samples of *Microtus paroperarius*, but is also known to be similar or identical to the living *Microtus oeconomus* (van der Meulen 1978). Additionally, this morphology is known to occur in very low percentages in some other extant species of *Microtus* (Bell and Repenning 1999).

Fifty of the 296 arvicoline specimens (16.9%) were identified as *Lemmiscus curtatus*. The only previous report of *Lemmiscus* from SCC was based on specimens collected from a back-dirt pile in the cave (Bell and Mead 1998). I identified both four- and five-triangle forms (Figure 5). The five-triangle form is most common, comprising 45 of the 50 specimens (90%) of *Lemmiscus curtatus* (Figure 5A). These specimens are characterized by the presence of five closed triangles and a well-developed T6 that is confluent with the anterior cap. They exhibit equal (or roughly equal) labial-lingual lengths in T1 and T2, a character that distinguishes them from *Microtus*, which has a labial-lingual width of T1 that is larger than T2 (Barnosky and Rasmussen 1998). Five specimens represent a four-triangle form where the fourth triangle is either confluent (not figured), pinched (Figure 5B, C), or has incipient closure (not figured) with respect to T5.

Four-triangle forms of *Lemmiscus curtatus* are noteworthy because that morphology is not known to occur in extant populations of sagebrush voles (Bell and Barnosky 2000; Barnosky and Bell 2003), and the loss of this morphotype may represent one of the few small mammal 'extinction' events near the early Holocene (Bell and Jass 2004). Smith Creek Cave represents one of the few localities known to preserve specimens of *Lemmiscus curtatus* that have a four-triangle morphology (other localities were reviewed by Bell and Jass 2004). Given the fact that three of the localities containing a four-triangle form of *Lemmiscus curtatus* occur in, or near Smith Creek Canyon, it seems a strong possibility that additional Pleistocene localities in

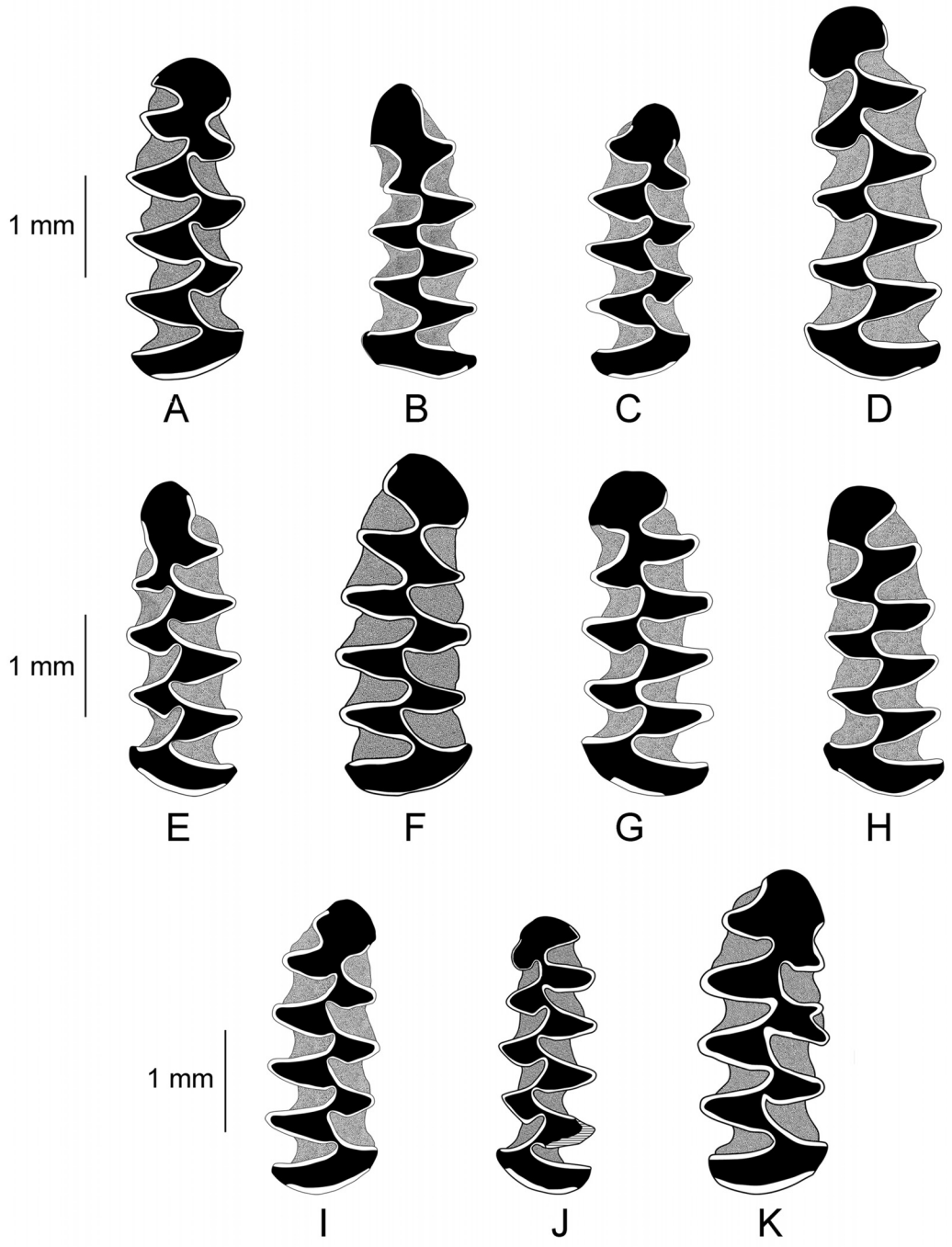

FIGURE 3. Variation in the morphology of *Microtus* sp. from Smith Creek Cave. **A**. *Microtus* sp. with five closed triangles (SCCAR-255). **B**. *Microtus* sp. with five closed triangles and confluent T1 and T2 (SCCAR-2). **C**. *Microtus* sp. with five closed triangles and a pinched T6 (SCCAR-9). **D**. *Microtus* sp. with five closed triangles, a pinched T6, and a T7 that is closed from the anterior cap (SCCAR-151). **E**. *Microtus* sp. with five closed triangles and a T6 with incipient closure (SCCAR-52). **F**. *Microtus* sp. with five closed triangles and secondary wings that are closed from the anterior cap (SCCAR-254). **G**. *Microtus* sp. with five closed triangles and secondary wings that are pinched from the anterior cap (SCCAR-166). **H**. *Microtus* sp. with five closed triangles and secondary wings with incipient closure from the anterior cap (SCCAR-16). **I**. *Microtus* sp. with six closed triangles. **J**. *Microtus* sp. with seven closed triangles (SCCAR-250). **K**. *Microtus* sp. with aberrant enamel pattern on T4 (SCCAR-115).

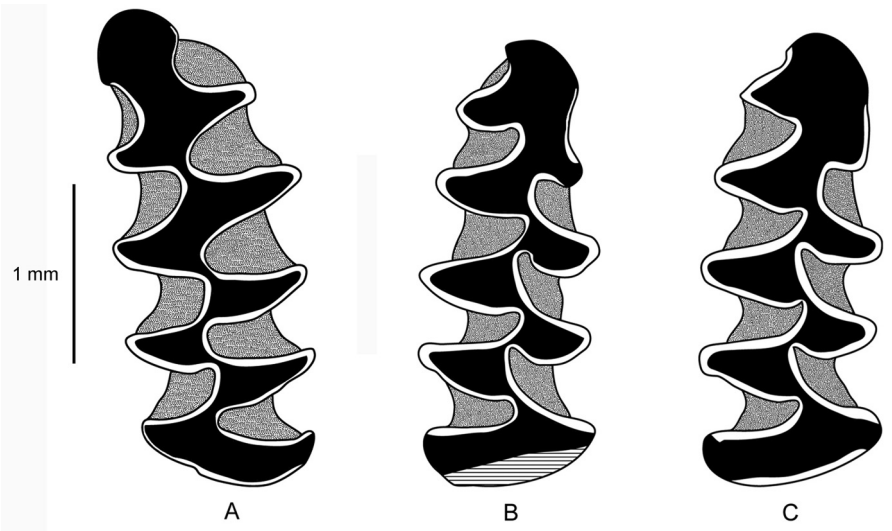

FIGURE 4. Specimens of *Microtus meadensis* and *M. paroperarius* from Smith Creek Cave. **A**. Left m1 of *M. meadensis* (SCCAR-27). **B**. Right m1 of *M. paroperarius* (SCCAR-25). **C**. Right m1 of *M. paroperarius* (SCCAR-212).

the vicinity (e.g., Crystal Ball Cave) may also preserve this morphotype.

In addition to the specimens reported here, two other arvicoline rodent taxa were reported from SCC. A single specimen (NAUQSP 17910) of *Phenacomys* that was collected from a back-dirt pile in SCC is housed at the Laboratory of Quaternary Paleontology, Northern Arizona University. The specimen was not examined for this study but was described and illustrated by Mead et al. (1982) as *Phenacomys* cf. *P. intermedius* and by Repenning and Grady (1988) as *Phenacomys albipes*.

Specimens of *Mictomys borealis* were reported from both Cathedral Cave and Smith Creek Cave (Mead et al. 1992). The record from Cathedral Cave consists of multiple specimens, but only a single M2 was reported from SCC. A subsequent re-examination of arvicoline rodents from Cathedral Cave (Bell 1995) revised the identification of *Mictomys borealis* but did not address the specimen from SCC. During the course of this study, no additional specimens of *Mictomys* were found in the SCC material housed at the Nevada State Museum. In the absence of additional specimens of *Mictomys* from SCC (e.g., m1s) that would allow for a more confident taxonomic placement, I consider the single record reported by Mead et al. (1992) to be *Mictomys* sp.

DISCUSSION

Consideration of the arvicoline rodent fauna from SCC in a broad biochronologic context raises interesting issues regarding the age of the reddish-pink silt stratum. With the exception of *Microtus paroperarius* and *M. meadensis*, the arvicoline rodent taxa identified from SCC are known to occur as recently as the early Holocene (four-triangle morphotype of *Lemmiscus curtatus*), or as components of the extant biota (*Lemmiscus curtatus*, *Microtus* sp., *Mictomys* sp., and *Phenacomys* sp.). However, records of *Phenacomys* and *Mictomys* at SCC and in central portions of the Great Basin represent disjunct geographic occurrences given the known modern distribution of these taxa in areas to the north, east, and west of the Great Basin (Grayson 1981; Mead et al. 1982, 1992).

One of the two *Microtus meadensis* specimens came from a layer of rodent dung and brown silt that was situated stratigraphically above the reddish-pink silt. There are no radioisotopic dates associated with this layer, but the color of this specimen, and specimens of *Microtus* sp. from the same level, suggest that they were mixed from the reddish-pink silt zone. Extensive rodent burrows were noted during the excavation (Bryan 1979; Miller 1979) and may explain the presence of a red-stained tooth above the reddish-pink silt.

Recent biochronologic summaries report the known age distributions of *Microtus paroperarius* as ~840 ka to 252 ± 30 Ka and that of *Microtus meadensis* as 820 ka to 252 ± 30 Ka (Bell et al. 2004a, 2004b). Given updated last occurrences from Cathedral Cave (146.02 ± 2.584 - 153.7 ± 6.4 Ka; Jass 2007; Jass and Bell in press), the pres-

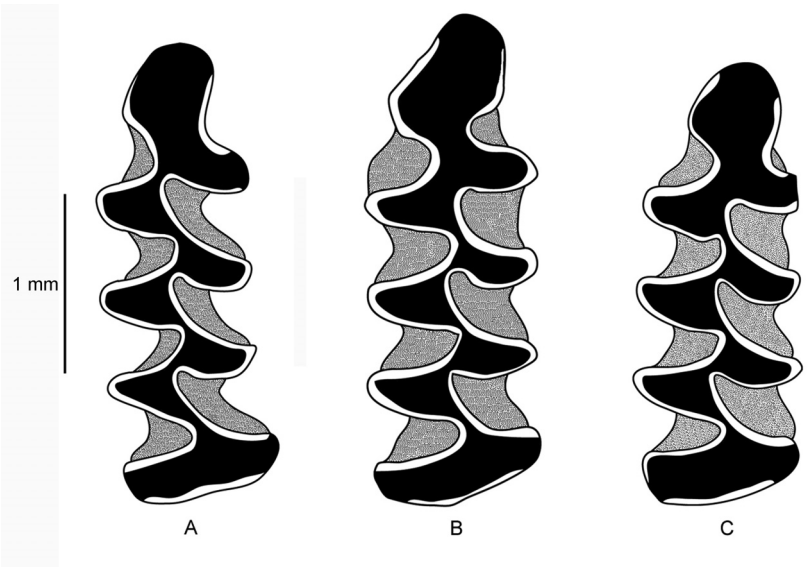

FIGURE 5. *Lemmiscus curtatus* from Smith Creek Cave. **A**. *Lemmiscus curtatus* with five closed triangles (SCCAR-261). **B**. *Lemmiscus curtatus* with four closed triangles and a pinched T5 (SCCAR-118). **C**. *Lemmiscus curtatus* with four closed triangles and a pinched T5 (SCCAR-106).

ence of *M. paroperarius* and *M. meadensis* at SCC imply an age between 820 ka and 146.02 ± 2.584 - 153.7 ± 6.4 Ka for the reddish-pink silt, based on maximum and minimum ages of all arvicolines from the site. A strictly biochronologic age estimate for the reddish-pink silt suggests a minimum difference of approximately 117 Ka between that stratum and the overlying archaeological deposits. A disconformity of 117 Ka does not seem particularly daunting or improbable in the context of an open-air deposit. However, within the confined context of a cave deposit, even a relatively open rock shelter like SCC, such a disconformity in vertical sequence would be rare.

Conversely, there is no explicit reason to rule out an alternate interpretation whereby SCC contains chronologic range extensions for both *Microtus paroperarius* and *Microtus meadensis* to as recently as 28,650 ± 760 ^{14}C yr BP. Although I was not able to reconstruct confidently the vertical relationships of the specimens from the reddish-pink silt because provenience data varied in scope and detail, I consider all taxa from the reddish-pink silt to be derived from a single stratigraphic level that has an associated radiocarbon age of 28,650 ± 760 ^{14}C yr BP. The stratigraphic information provided by Bryan (1979) indicates that the reddish-pink silt represents a discrete stratum, and the unique color of bone from the reddish-pink silt supports this interpretation. As mentioned above, the radiocarbon date for the reddish-pink silt level was based on bone collagen. In the absence of additional radioisotopic testing using newer collagen extraction techniques or testing on more reliable materials (e.g., charcoal, twigs; see Meltzer and Mead 1985 for discussion), an outright dismissal of the radiocarbon age would be premature.

Another possibility would be that both biochronologic and radioisotopic (^{14}C yr BP) age assignments are incorrect and another age represents the “true” age (or ages) of the red silt zone. In many respects, the chronologic quandary regarding arvicoline rodent biochronology versus radioisotopic data from SCC is similar to that encountered at Cathedral Cave, a paleontological site situated directly across the canyon from SCC, where there were significant differences between biochronologic age estimates and initial radioisotopic ages for the site (see Mead et al. 1992; Bell 1995; Jass 2005; Jass and Bell in press). Fine-scale (5 cm levels) excavation, uranium-series analysis, and paleomagnetic analysis in relation to the occurrence of arvicolines throughout the excavated sedimentary levels has contributed to resolving chronological discrepancies at Cathedral Cave (Jass 2007; Jass and Bell in press). If comparable sedimentary levels still exist within SCC, additional radioisotopic dating (e.g., AMS on bone collagen and charcoal) and further fieldwork focused on micro-sampling the reddish-pink silt zone might help clarify the distribution of *Microtus meadensis* and *Microtus paroperarius* within the sedimentary successsion of SCC.

A fourth possibility is that the specimens represent population variants of *Microtus* and are chronologically uninformative. Variation in the dentition of extant and fossil *Microtus* is common and widely recognized within species (e.g., Paulson 1961; van der Meulen 1978; Guilday 1982; Weddle and Choate 1983; Martin 1987, 1993; Harris 1988; Barnosky 1990, 1993; Pfaff 1990; Bell and Repenning 1999; Gordon 1999). Because morphologies that resemble *Microtus meadensis* and *Microtus paroperarius* are known from extant populations, the possibility that the SCC specimens represent population variants of extant taxa must be acknowledged. I am hesitant to accept such an interpretation because of the presence of similar morphotypes found in association with other extinct taxa (e.g., *Mictomys* cf. *M. meltoni* or *M. kansasensis*) at Cathedral Cave, situated across the canyon from SCC, and observations of arvicoline m1s in the back dirt pile of SCC.

Both *Microtus meadensis* and *Microtus paroperarius* are known in higher percentages (2.4% and 6.6%, respectively) relative to the total number of arvicolines at nearby Cathedral Cave (Jass 2007; Jass and Bell in press). Independent age estimates indicate a maximum age between 146.02 ± 2.584 - 153.7 ± 6.4 Ka for the Cathedral Cave fauna (Jass 2007; Jass and Bell in press). The data from Cathedral Cave indicate the presence of both taxa in Smith Creek Canyon during the Pleistocene. Although the abundance of these taxa in SCC is lower than in Cathedral Cave, it seems reasonable to infer that *Microtus meadensis* and *M. paroperarius* may be represented by the morphologies described above.

The recognition of abundant arvicoline m1s in the backdirt pile of SCC (Jass personal observation; Mead et al. 1982, 1992; Bell and Mead 1998) suggests that many excavated arvicoline specimens were missed in the original collection process. As pointed out by Miller (1979), much of the osteological material was recovered using 0.25-inch (6.35 mm) mesh screens, and this likely contributed to the loss of many arvicoline specimens. Therefore, the sample examined for this study is likely biased toward larger specimens. There is no explicit reason to suspect that this contributed to bias in the recovery of one morphotype versus another, but it does increase my reluctance to classify the low percentages of *Microtus meadensis* and *Microtus paroperarius* morphotypes as morphological variants of extant species of *Microtus*. At the least, the use of this taxonomy calls attention to the specimens and the variation in the m1 of *Microtus* from SCC. Future research at SCC and/or further evaluation of dental variation in *Microtus* may alter this taxonomic interpretation. Re-screening of the backdirt piles for arvicoline specimens would also produce additional materials that could be used to further evaluate the rarity of m1s of *Microtus meadensis* and *Microtus paroperarius.*

A final possibility to explain the conflicting age data is that the reddish-pink silt layer represents a broadly time-averaged unit where older fossil forms (e.g. *Microtus paroperarius*) occur with more recent specimens. Multiple processes (e.g., mixing, slow accumulation rates) can produce broadly time-averaged deposits, and scales of time-averaging in cave deposits can vary dramatically from hundreds of years (Hadly 1999; Hadly and Maurer 2001) to thousands of years (Barnosky et al. 2004). Because time-averaging can vary over such a broad scale in cave deposits, the evaluation of independent data sets with respect to questions concerning site chronologies is essential.

Specific resolution of the non-congruence of biochronologic and radiocarbon data at SCC is not possible at this time, but the recognition that there is disagreement in these data sets has broad implications for other studies that would seek to incorporate paleontological data from the site, and the reddish-pink silt stratum in particular. The inconsistency in the chronological data sets from SCC illustrates the complexity in attaining chronologic resolution throughout fossil sequences preserved in caves.

Caves represent complex depositional settings (Sutcliffe 1970; Gillieson 1996) and SCC is no exception. Multiple processes (anthropogenic, biologic, chemical, and geologic) contributed to the deposition of sediments at the site, and served to alter and modify the deposit (Bryan 1979). In a sense, sedimentary deposits like the ones preserved in SCC represent a microcosm of the larger-scale sedimentary processes that shape larger, open-air deposits. Some geologic features observed on broad scales in outcrop (e.g., unconformities) may occur within sedimentary deposits within caves. However, because of spatial restrictions in caves, the geologic processes that impact cave deposits seem magnified relative to similar processes in larger, open-air, sedimentary systems. When geologic processes, such as bioturbation, occur in the restricted geographic space of a cave deposit like SCC, the complexity of the deposit potentially increases more rapidly than a similar process occurring over a larger area (e.g., extensive, open-air deposits).

Similarly, the impact of conducting an excavation within a cave deposit can have more significant long-term impacts on future work than is seen in many other field settings. For this study, my capability for accurately interpreting the chronologic implications of the arvicoline fauna was directly related to previous work on the site, including collection methods, the reporting of site stratigraphy, and the retention of provenience information associated with individual specimens. Returning to SCC to conduct additional fieldwork may not result in comparable data to those considered here. Once a portion of a cave deposit is removed, a unique piece of geologic history is taken out of the record, with no guarantee that sediments left behind for future generations to examine represent comparable or even time-equivalent data sets. Previous research has clearly shown that caves may contain multiple unique deposits of differing ages across distinct portions of a cave (e.g., Lundelius 1985). Therefore, careful attention to detail in the reporting of cave excavations and recording of associated data (e.g., provenience data) is important to ensure that new analytical techniques or approaches can be accurately considered within the context of previously developed stratigraphies or chronologies.

My re-examination of the arvicoline fauna from SCC does suggest a potentially unique situation with respect to North American cave deposits, in that the site may preserve fossiliferous sediments of disparate age in vertical succession. This sequence may represent something real about the nature of fossil preservation in cave deposits, or may reflect a relatively short (geologically speaking) existence of such deposits in western North America. Methodological limitations for attaining accurate radioisotopic age control on sites that predate radiocarbon (i.e., > 60,000 yr B.P.) may be contributing to a skewed understanding of the age of fossils preserved in North American caves. However, I hypothesize that it may be (in part) an artifact of the abundance of cave deposits that contain terminal Pleistocene-Recent sediments and the heavy research emphasis from both paleontologists and archaeologists on questions relating to deposits of this age. Perhaps the paucity of sites containing pre-terminal Pleistocene sediments is partially an artifact of research bias or interest. Whatever the reason, the presence of *Microtus paroperarius* and *Microtus meadensis* at SCC should serve as a reminder that caves are complex depositional systems, and that researchers must at least be aware of the potential for significant time-averaging and/or disconformities in the vertical sequences excavated from them.

CONCLUSIONS

Quaternary cave deposits retain a wealth of information that can be used to establish site chronologies and reconstruct past biotic conditions. Because fossiliferous deposits within caves are spatially limited, and potentially time-transgressive across a given area, the retention of stratigraphic and provenience data associated with individual fossils is essential. The recognition of unique arvicoline morphotypes from the reddish-pink silt stratum at SCC suggests that our understanding of the chronology of the site is incomplete. Notable additions to the arvicoline record from SCC include *Microtus paroperarius*, *Microtus meadensis*, and a four-triangle morphotype of *Lemmiscus curtatus*. The identification of *Microtus paroperarius* and *Microtus meadensis* suggest the possibility of an older age for the reddish-pink silt zone than was indicated by radiocarbon dating. The presence of these arvicoline taxa in the context of the known stratigraphy and chronology for SCC re-emphasizes advantages (e.g., independent data sets) and complexities (e.g., spatial limitation, disturbance) in conducting research on faunas from cave deposits.

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APPENDIX 1

List of specimens identified in this study. S.N. equals Specimen Number. Individual specimen numbers are preceded in the text by the acronym SCCAR-; citation of individual specimens should include this acronym. Abbreviations for stratigraphic units (Strat.Unit) are as follows: R/P Silt equals reddish/pink silt; RD/BS equals rodent dung and brown silt layer; U/Q equals unknown or questionable provenience. There is no specimen assigned SCCAR-116 because the specimen originally allocated that number was discovered to be from a different locality and was excluded from this report.

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
1	*Microtus* sp.	R	m1	5T	R/P Silt	
2	*Microtus* sp.	L	Partial dentary with i1, m1	5T, T1-T2 confluent	R/P Silt	
3	*Microtus* sp.	L	Partial dentary with i1, m1-m2	5T	R/P Silt	
4	*Microtus* sp.	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
5	*Microtus* sp.	R	m1	5T	R/P Silt	
6	*Microtus* sp.	R	m1	5T	R/P Silt	
7	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
8	*Microtus* sp.	R	m1	5T	R/P Silt	
9	*Microtus* sp.	R	m1	5T, T6 pinched	R/P Silt	
10	*Microtus* sp.	R	m1	5T	R/P Silt	
11	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
12	*Microtus* sp.	L	m1	5T	R/P Silt	
13	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
14	*Microtus* sp.	L	m1	5T	R/P Silt	
15	*Microtus* sp.	R	Dentary with i1, m1-m2	5T	R/P Silt	
16	*Microtus* sp.	L	m1	5T, T6/T7 w/ incipient closure	R/P Silt	
17	*Microtus* sp.	R	m1	5T	R/P Silt	
18	*Microtus* sp.	R	m1	5T	R/P Silt	
19	*Microtus* sp.	L	Partial dentary with m1-m2	5T	R/P Silt	
20	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
21	*Microtus* sp.	L	Partial dentary with m1-m2	5T	R/P Silt	
22	*Microtus* sp.	R	m1	5T	R/P Silt	
23	*Microtus* sp.	R	m1	5T	R/P Silt	
24	*Microtus* sp.	L	m1	5T	R/P Silt	
25	*Microtus paroperarius*	R	m1	-	R/P Silt	
26	*Microtus* sp.	L	Dentary with i1, m1-m2	5T	RD/BS	
27	*Microtus meadensis*	L	m1	-	RD/BS	
28	*Microtus* sp.	L	m1	5T	RD/BS	
29	*Microtus* sp.	R	m1	5T	RD/BS	
30	*Microtus* sp.	R	m1	6T	RD/BS	
31	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
32	*Microtus* sp.	L	m1	5T	R/P Silt	
33	*Microtus* sp.	R	m1	5T, T6 pinched	R/P Silt	
34	*Microtus* sp.	R	m1	5T, T6 pinched	R/P Silt	digested
35	*Microtus* sp.	R	m1	5T	R/P Silt	
36	*Microtus* sp.	R	m1	5T	R/P Silt	
37	*Microtus* sp.	R	m1	5T	R/P Silt	
38	*Microtus* sp.	L	m1	5T	R/P Silt	
39	*Microtus* sp.	L	m1	5T	R/P Silt	
40	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
41	*Microtus* sp.	R	m1	5T	R/P Silt	
42	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
43	*Microtus* sp.	R	m1	5T	R/P Silt	
44	*Microtus meadensis*	R	m1	-	R/P Silt	
45	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
46	*Microtus* sp.	R	m1	5T	R/P Silt	
47	*Microtus* sp.	L	m1	5T	R/P Silt	digested
48	*Microtus* sp.	L	Partial dentary with i1, m1-m2	5T	U/Q	
49	*Microtus* sp.	L	Dentary with i1, m1-m3	5T	R/P Silt	
50	*Microtus* sp.	R	m1	5T	R/P Silt	
51	*Microtus* sp.	R	m1	5T	R/P Silt	
52	*Microtus* sp.	L	m1	5T, T6 pinched	R/P Silt	
53	*Microtus* sp.	R	m1	5T, T6 w/ incipient closure	R/P Silt	
54	*Microtus* sp.	R	m1	5T	R/P Silt	
55	*Microtus* sp.	L	m1	5T	R/P Silt	
56	*Microtus* sp.	L	m1	5T	R/P Silt	
57	*Microtus* sp.	L	Partial dentary with i1, m1-m2	5T	R/P Silt	
58	*Microtus* sp.	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
59	*Lemmiscus curtatus*	R	Dentary with m1-m2	5T	R/P Silt	
60	*Microtus* sp.	L	m1	5T	R/P Silt	
61	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
62	*Microtus* sp.	R	m1	5T, T6 pinched	R/P Silt	
63	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
64	*Microtus paroperarius*	L	m1	-	R/P Silt	
65	*Microtus* sp.	R	m1	5T	R/P Silt	
66	*Microtus* sp.	L	m1	5T, T6 pinched	R/P Silt	
67	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
68	*Microtus* sp.	L	m1	5T	R/P Silt	
69	*Microtus* sp.	R	m1	5T, T6 w/ incipient closure	R/P Silt	
70	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
71	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
72	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
73	*Microtus* sp.	R	m1	5T	R/P Silt	
74	*Microtus* sp.	R	m1	5T	R/P Silt	
75	*Microtus* sp.	L	m1	5T	R/P Silt	
76	*Microtus* sp.	R	m1	5T, T6 pinched	R/P Silt	
77	*Microtus* sp.	L	m1	5T	R/P Silt	
78	*Microtus* sp.	R	m1	5T	R/P Silt	
79	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
80	*Microtus* sp.	R	m1	5T	R/P Silt	
81	*Microtus* sp.	L	m1	5T	R/P Silt	
82	*Microtus* sp.	R	m1	5T	R/P Silt	
83	*Microtus* sp.	L	m1	5T	R/P Silt	
84	*Microtus* sp.	L	m1	5T	R/P Silt	
85	*Microtus* sp.	R	m1	6T	R/P Silt	
86	*Microtus* sp.	R	m1	5T	R/P Silt	
87	*Microtus* sp.	L	m1	5T	R/P Silt	
88	*Microtus* sp.	R	m1	5T	R/P Silt	
89	*Microtus* sp.	L	m1	5T	R/P Silt	
90	*Microtus* sp.	L	m1	5T	R/P Silt	
91	*Microtus* sp.	L	Dentary with i1, m1-m2	5T	R/P Silt	
92	*Microtus* sp.	L	m1	5T, T6 pinched	R/P Silt	
93	*Microtus* sp.	R	m1	5T	R/P Silt	

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
94	*Microtus* sp.	L	m1	5T, T6 pinched	R/P Silt	
95	*Lemmiscus curtatus*	R	Partial dentary with m1	5T	R/P Silt	
96	*Microtus* sp.	R	m1	5T	R/P Silt	
97	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
98	*Microtus* sp.	R	m1	5T, T6 pinched	R/P Silt	
99	*Microtus* sp.	L	m1	5T, T6 pinched	R/P Silt	
100	*Microtus* sp.	L	m1	5T	R/P Silt	
101	*Microtus* sp.	L	m1	5T	R/P Silt	
102	*Microtus* sp.	R	m1	5T	R/P Silt	
103	*Microtus* sp.	R	m1	5T	R/P Silt	
104	*Microtus* sp.	R	m1	5T	R/P Silt	
105	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
106	*Lemmiscus curtatus*	R	m1	4T, T5 pinched	R/P Silt	
107	*Microtus* sp.	R	Dentary with i1, m1-m2	5T	R/P Silt	
108	*Microtus* sp.	L	Dentary with i1, m1-m2	5T	R/P Silt	
109	*Microtus* sp.	L	m1	5T	R/P Silt	
110	*Microtus* sp.	L	m1	5T	R/P Silt	
111	*Microtus* sp.	R	m1	5T	R/P Silt	
112	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
113	*Microtus* sp.	L	Dentary with i1, m1	5T	R/P Silt	
114	*Microtus* sp.	L	m1	5T	R/P Silt	
115	*Microtus* sp.	R	m1	5T	U/Q	
117	*Microtus* sp.	R	Dentary with i1, m1-m3	5T	R/P Silt	
118	*Lemmiscus curtatus*	R	m1	4T	R/P Silt	
119	*Microtus* sp.	L	m1	5T	R/P Silt	
120	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
121	*Microtus* sp.	R	m1	5T	R/P Silt	
122	*Microtus* sp.	R	m1	5T	R/P Silt	
123	*Microtus* sp.	L	m1	5T	R/P Silt	
124	*Microtus* sp.	L	m1	5T	R/P Silt	
125	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
126	*Microtus* sp.	L	m1	5T	R/P Silt	
127	*Lemmiscus curtatus*	L	Dentary with i1, m1	5T	R/P Silt	
128	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
129	*Lemmiscus curtatus*	R	m1	4T	R/P Silt	
130	*Microtus* sp.	L	m1	5T	R/P Silt	
131	*Microtus* sp.	L	m1	5T	R/P Silt	
132	*Microtus* sp.	L	m1	5T	R/P Silt	
133	*Microtus* sp.	R	m1	6T	R/P Silt	
134	*Microtus* sp.	L	Dentary with i1, m1-m2	5T	R/P Silt	
135	*Lemmiscus curtatus*	L	Partial dentary with i1, m1-m2	5T	R/P Silt	
136	*Microtus* sp.	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
137	*Microtus* sp.	R	Partial dentary with m1-m2	5T	R/P Silt	
138	*Microtus* sp.	R	Dentary with i1 (fragment), m1-m2	5T	R/P Silt	
139	*Microtus* sp.	L	m1	5T	R/P Silt	
140	*Microtus* sp.	R	m1	6T	R/P Silt	
141	*Microtus* sp.	R	m1	5T	R/P Silt	
142	*Microtus* sp.	L	m1	6T	R/P Silt	
143	*Microtus* sp.	R	m1	5T	R/P Silt	
144	*Microtus* sp.	L	m1	5T	R/P Silt	
145	*Microtus* sp.	L	m1	5T	R/P Silt	
146	*Microtus* sp.	R	m1	5T, T6/T7 closed	R/P Silt	

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
147	*Microtus* sp.	R	m1	5T	R/P Silt	
148	*Microtus* sp.	L	m1	5T	R/P Silt	
149	*Microtus* sp.	R	m1	5T	R/P Silt	
150	*Microtus* sp.	L	m1	5T	R/P Silt	
151	*Microtus* sp.	L	m1	5T, T6 pinched from T7; T7 closed from cap	R/P Silt	
152	*Microtus* sp.	L	m1	5T	R/P Silt	
153	*Microtus* sp.	R	m1	5T	R/P Silt	
154	*Microtus* sp.	R	m1	5T	R/P Silt	
155	*Microtus* sp.	R	m1	5T	R/P Silt	
156	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
157	*Microtus* sp.	R	m1	5T	R/P Silt	
158	*Microtus* sp.	R	m1	5T	R/P Silt	
159	*Microtus* sp.	R	m1	5T	R/P Silt	
160	*Microtus* sp.	R	m1	5T	R/P Silt	
161	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
162	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
163	*Microtus* sp.	R	m1	5T	R/P Silt	
164	*Lemmiscus curtatus*	L	m1	4T, T5 pinched	R/P Silt	
165	*Microtus* sp.	L	Partial dentary with m1-m2	5T, T6 pinched	R/P Silt	
166	*Microtus* sp.	L	m1	5T, T6/T7 pinched from cap	R/P Silt	
167	*Microtus* sp.	R	m1	5T	R/P Silt	
168	*Microtus* sp.	R	m1	5T	R/P Silt	
169	*Microtus* sp.	R	Partial dentary with i1, m1-m2	5T	U/Q	
170	*Microtus* sp.	L	Partial dentary with i1, m1-m2	5T, T6 pinched	U/Q	
171	*Microtus* sp.	R	m1	5T	U/Q	
172	*Microtus* sp.	L	m1	6T	U/Q	
173	*Microtus* sp.	R	Partial dentary with m1-m2	5T	R/P Silt	
174	*Microtus* sp.	R	Partial m1	5T	R/P Silt	
175	*Microtus* sp.	L	m1	5T	R/P Silt	
176	*Microtus* sp.	L	m1	5T	R/P Silt	
177	*Microtus* sp.	R	m1	5T	R/P Silt	
178	*Microtus* sp.	R	m1	5T	R/P Silt	
179	*Microtus* sp.	L	m1	5T	R/P Silt	
180	*Microtus* sp.	R	m1	5T	R/P Silt	
181	*Microtus* sp.	L	Partial dentary with i1, m1	5T	R/P Silt	
182	*Microtus* sp.	L	Partial dentary with m1-m2	5T	R/P Silt	juvenile
183	*Microtus* sp.	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
184	*Microtus* sp.	R	m1	5T	R/P Silt	
185	*Microtus* sp.	R	m1	5T	R/P Silt	
186	*Microtus* sp.	R	m1	5T	R/P Silt	
187	*Microtus* sp.	R	m1	5T, T6/T7 closed	R/P Silt	
188	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
189	*Microtus* sp.	L	m1	5T	R/P Silt	
190	*Microtus* sp.	L	m1	5T	R/P Silt	
191	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
192	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
193	Arvicolinae	R	m1	-	R/P Silt	
194	*Microtus* sp.	L	m1	5T	R/P Silt	
195	*Microtus* sp.	R	m1	5T	R/P Silt	
196	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
197	*Microtus* sp.	L	m1	5T	R/P Silt	
198	*Microtus* sp.	R	m1	5T	R/P Silt	
199	*Microtus* sp.	R	Partial dentary with m1-m2	5T	R/P Silt	
200	*Lemmiscus curtatus*	R	Dentary with i1, m1-m2	5T	R/P Silt	
201	*Microtus* sp.	L	m1	5T	R/P Silt	
202	*Microtus* sp.	L	m1	5T	R/P Silt	
203	*Microtus* sp.	R	m1	-	R/P Silt	
204	*Microtus* sp.	L	m1	5T	R/P Silt	
205	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
206	*Microtus* sp.	R	m1	5T	R/P Silt	
207	*Microtus* sp.	R	m1	5T	R/P Silt	
208	*Microtus* sp.	R	m1	5T	R/P Silt	
209	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
210	*Microtus* sp.	R	m1	5T	R/P Silt	
211	*Microtus* sp.	L	Partial dentary with m1 (broken)	6T	U/Q	
212	*Microtus paroperarius*	R	m1	-	R/P Silt	
213	*Microtus* sp.	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
214	*Microtus* sp.	R	Partial dentary with m1-m2	6T	R/P Silt	
215	*Microtus* sp.	R	Partial dentary with i1, m1-m2	5T, T6 pinched	R/P Silt	
216	*Microtus* sp.	L	Partial dentary with m1-m2	6T	R/P Silt	
217	*Microtus* sp.	L	m1	5T	R/P Silt	
218	*Microtus* sp.	L	m1	5T	R/P Silt	
219	*Microtus* sp.	L	m1	6T	R/P Silt	
220	*Microtus* sp.	R	m1	5T	R/P Silt	
221	*Microtus* sp.	L	m1	5T	R/P Silt	
222	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
223	*Microtus* sp.	R	m1	5T	R/P Silt	
224	*Microtus* sp.	R	m1	5T	R/P Silt	
225	*Microtus* sp.	R	m1	5T	R/P Silt	
226	*Microtus* sp.	R	m1	5T	R/P Silt	
227	*Microtus* sp.	L	m1	5T	R/P Silt	
228	Arvicolinae	R	m1?		R/P Silt	
229	*Microtus* sp.	L	Partial dentary with m1	5T	R/P Silt	
230	*Microtus* sp.	L	m1	5T	R/P Silt	
231	*Microtus* sp.	L	m1	5T	R/P Silt	
232	*Microtus* sp.	R	m1	5T	R/P Silt	
233	*Microtus* sp.	L	m1	5T	R/P Silt	
234	*Microtus* sp.	R	Partial dentary with m1-m2	5T	R/P Silt	
235	*Microtus* sp.	R	Partial dentary with m1	5T	R/P Silt	juvenile
236	*Microtus* sp.	L	m1	5T, T6 w/ incipient closure	R/P Silt	
237	*Microtus* sp.	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
238	*Microtus* sp.	L	m1	5T	R/P Silt	
239	*Microtus* sp.	L	m1	5T	R/P Silt	
240	*Microtus* sp.	R	m1	6T	R/P Silt	
241	*Microtus* sp.	R	m1	5T	R/P Silt	
242	*Microtus* sp.	R	m1	5T	R/P Silt	
243	*Microtus* sp.	R	m1	6T	R/P Silt	
244	*Microtus* sp.	L	m1	5T	R/P Silt	
245	*Microtus* sp.	L	m1	5T, T6 pinched	R/P Silt	
246	*Microtus* sp.	L	m1	5T	R/P Silt	
247	*Microtus* sp.	L	m1	5T	R/P Silt	

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
248	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
249	*Microtus* sp.	L	m1	5T	R/P Silt	
250	*Microtus* sp.	L	m1	7T	R/P Silt	
251	*Microtus* sp.	R	m1	5T	R/P Silt	
252	*Microtus* sp.	L	m1	6T	R/P Silt	
253	*Microtus* sp.	L	m1	5T	R/P Silt	
254	*Microtus* sp.	R	m1	5T, T6/T7 closed from cap	R/P Silt	
255	*Microtus* sp.	R	m1	5T	R/P Silt	
256	*Microtus* sp.	L	m1	6T	R/P Silt	
257	*Microtus* sp.	L	m1	5T	R/P Silt	
258	*Microtus* sp.	R	m1	5T	R/P Silt	
259	*Microtus* sp.	R	m1	5T	R/P Silt	
260	*Microtus* sp.	L	m1	5T	R/P Silt	
261	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
262	*Microtus* sp.	R	Dentary with m1-m2	6T	R/P Silt	
263	*Microtus* sp.	L	Partial dentary with i1, m1	5T	R/P Silt	
264	*Microtus* sp.	L	Dentary with i1, m1-m2	5T	R/P Silt	
265	*Microtus* sp.	L	m1	5T	R/P Silt	digested
266	*Microtus* sp.	L	m1	5T	R/P Silt	
267	*Microtus* sp.	L	m1	5T	R/P Silt	
268	*Microtus* sp.	L	m1	5T, T6 pinched	R/P Silt	
269	*Microtus* sp.	R	m1	5T	R/P Silt	
270	*Microtus* sp.	L	m1	5T	R/P Silt	
271	*Microtus* sp.	L	m1	5T	R/P Silt	
272	*Microtus* sp.	R	m1	5T	R/P Silt	
273	*Microtus* sp.	L	m1	5T	R/P Silt	
274	*Microtus* sp.	L	m1	5T	R/P Silt	
275	*Microtus* sp.	L	m1	5T	R/P Silt	
276	*Microtus* sp.	L	m1	5T	R/P Silt	
277	*Microtus* sp.	L	m1	5T	R/P Silt	
278	*Microtus* sp.	L	m1	5T	R/P Silt	
279	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
280	*Microtus* sp.	L	m1	5T	R/P Silt	
281	*Microtus* sp.	L	Dentary with i1, m1-m2	5T	R/P Silt	
282	*Microtus* sp.	R	m1	5T	R/P Silt	
283	*Microtus* sp.	R	m1	5T	R/P Silt	
284	*Microtus* sp.	R	m1	5T	R/P Silt	
285	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
286	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
287	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
288	*Microtus* sp.	L	m1	5T	R/P Silt	
289	*Microtus* sp.	R	m1	5T	R/P Silt	
290	*Microtus* sp.	L	m1	5T	R/P Silt	
291	*Lemmiscus curtatus*	R	m1	4T, T5 w/ incipient closure	R/P Silt	
292	*Microtus* sp.	R	m1	5T	R/P Silt	
293	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
294	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
295	*Microtus* sp.	R	Dentary with i1, m1-m2	5T	R/P Silt	
296	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
297	*Microtus* sp.	R	Partial Dentary with i1, m1-m2	5T	R/P Silt	

APPENDIX 2.

Provenience data associated with individual specimens by stratigraphic level. Data in brackets represents data listed on bone bags from which individual specimens were separated. <SD> indicates that a single SD (equals Surface Depth?) was written on the bag label in such a manner that it appears to apply to all associated numbers (e.g. SW 62-80 SD). Multiple specimens from a given provenience are indicated by double hyphens separating the first and last specimens in the sequence (e.g., SCCAR-2--SCCAR-14).

Reddish-Pink Silt--(26WP46, TP #2, 50-60 cm): SCCAR-1; (26WP46, Baulk #1/#2, Stratum 3, 25-40 cm B.S., Red silt and rock frags., July 20/71): SCCAR-2--SCCAR-14; (26WP46, Baulk #1/#2, 70-80 cm B.S., Stratum 5, Red Silt and rock, RM, July 24/71): SCCAR-15--SCCAR-17; (26WP46, TP #2, 60-70 cm, RM, July 18/71): SCCAR-18; (26WP46, Bulk, #1/#2, 0-70 cm, Stratum 5, Red Silt): SCCAR-19--SCCAR-20; (26WP46, TP #2, 90-100 cm): SCCAR-21--SCCAR-25; (26WP46/481, Level Bag TP3, Reddish/Pink Silt, 30-40 cm below surface of silt): SCCAR-31--SCCAR-44; (26WP46, TP #2, 100-110 cm): SCCAR-45--SCCAR-47; (26WP46, Baulk ext., Stratum 5, 50-60 cm): SCCAR-49; (26WP46, TP 3, North 50 cm, Red Layer): SCCAR-50--SCCAR-56; (26WP46, TP 3, “Pink Layer”, NW 38-71 <SD>, SW 62-80 <SD>, SE 82-86 <SD>, SJM, 7/12/74): SCCAR-57--SCCAR-90; (26WP46/488, Level Bag TP 3, Depth: 40-50 cm below surface of reddish/pink silt): SCCAR-91--SCCAR-100; (26WP46, Baulk #1/#2, 90-110, Stratum 5): SCCAR-101--SCCAR-106; (26WP46, Baulk #1/#2, 180-190 cm BS, Stratum 5, Red Silt and Rock): SCCAR-107--SCCAR-112; (26WP46, Baulk #1/#2, 140-150, Stratum 5): SCCAR-113--SCCAR-114; (26WP46, Baulk #1/#2, Stratum 5, 50-60): SCCAR-117--SCCAR-123; (26WP46, TP #3 70-80 cm in W half, 60-70 cm in E half, Northernmost 50 cm): SCCAR-124; (26WP46, TP 3, Northernmost 50 cm, 90-100 in W half): SCCAR-125; (26WP46, TP 3, Red Layer, To 40 in E half, 50 in W half, North 50 cm): SCCAR-126; (26WP46, TP 3, Top of Red Layer): SCCAR-127--SCCAR-133; (26WP46/437, TP3, “Bones”, “Pink Layer”, NW 38-71 <SD>, SW 62-80 <SD>, SE 82-86 <SD>, 7/10/74, 7/11/74, SJM): SCCAR-134--SCCAR-159; (26WP46, Baulk #1/#2, 130-140 cm BS, Stratum 5): SCCAR-160--SCCAR-161;(26WP46, Baulk #1/#2, 150-160 cm B.S., Stratum 5, Red Silt and Rock, RM, July 26/71): SCCAR-162--SCCAR-164; (26WP46, Baulk #1/#2, Stratum 5, 120-130 cm): SCCAR-165--SCCAR-168; (26WP46, Baulk ½, 50-60, Stratum 3): SCCAR-173--SCCAR-180; (26WP46/472, Level Bag TP 3, Reddish/pink silt zone, 20-30 cm below surface of silt): SCCAR-181--SCCAR-198; (26WP46/495, Level Bag TP 3, Reddish Pink Silt, 70-90 cm below surface of silt zone): SCCAR-199--SCCAR-206; (26WP46, Baulk Extension, #1/#2, Stratum 5, Red Silt and Rock, 40-50 cm, RM, July 22, 71): SCCAR-207--SCCAR-210; (26WP46, Baulk ½, 170-180, Stratum 5): SCCAR-212; (26WP46/490, Level Bag – reddish/pink silt zone, Depth 50-60 cm below surface of silt): SCCAR-213--SCCAR-224; (TP 2, RM, 30-50 cm BS, Teeth): SCCAR-225--SCCAR-252; (26WP46/492, Level Bag TP 3, Reddish/Pink Silt, Depth 60-70 cm below surface of reddish pink silt): SCCAR-253--SCCAR-261; (TP 2, RM, 30-50 cm, Teeth): SCCAR-262--SCCAR-266; (26WP46/468, Bone Fragments, From reddish/pink silt, 0-20 cm below surface of silt): SCCAR-267--SCCAR-294, SCCAR-297; (26WP46, TP 3, General Red Layer): SCCAR-295--SCCAR-296.

Rodent Dung and Brown Silt--(26WP46, Layer #2, TP 2, 20-30 cm): SCCAR-26--SCCAR-30.

Unknown/Questionable Provenience--(26WP46, TP 3, 80-90 W, 70-80 E): SCCAR-48; 26WH?/30, Level Bag, 30-40 cm below surface): SCCAR-115; (26WP46, TP 4, Baulk ¼, SD 10-20, Layer #2): SCCAR-169--SCCAR-172; (26WP46, TP 4, S.D., [SW 70 SE 64 NE 83 NW 77 to 1 m]): SCCAR-211.