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# Small mammals from the Sespe Formation (Arikareean) of Cañada Chiquita, Orange County, California

Thomas S. Kelly

Research Associate, Department of Vertebrate Paleontology, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles California 90007

ABSTRACT

A small sample of isolated teeth recently recovered from the Sespe Formation at Cañada Chiquita in Orange County, southern California, represents at least eight families of small mammals. Taxa identified in the sample include a heterosoricine lipotyphlan, the rabbit *Archaeolagus* sp., the rodents *Nototamias* sp., *Heliscomys* sp., *Tenudomys* sp., *Proheteromys* sp., cf. *Kirkomys* sp., cf. *Proharrymys* sp., *Leidymys nematodon*, and an indeterminate artiodactyl. This assemblage is referred to as the Cañada Chiquita Local Fauna and, based on the faunal composition, is Arikareean in age.

## INTRODUCTION

The continental Sespe Formation in the northern Santa Ana Mountains and along adjacent Loma Ridge in Orange County, southern California, is commonly mapped with the conformably overlying marine Vaqueros Formation as the undifferentiated Sespe-Vaqueros formations (S/V) (Morton and Miller, 1981; Schoellhamer at el., 1981). In those areas, the S/V contains alternating "Sespe" and "Vaqueros lithofacies" that are often difficult to separate in the field (Whistler and Lander, 2003). Elsewhere in Orange County, the Sespe and Vaqueros formations are mapped as distinct stratigraphic units (Morton and Miller, 1981). Whistler and Lander (2003) provided a detailed biostratigraphic framework for the Sespe Formation and S/V in Orange County, recognizing four superposed faunas of late Uintan, early and late Arikareean, and early Hemingfordian age.

In 2009, a paleontologic resource impact mitigation program was implemented in support of the construction of the Santa Margarita Water District's Upper Chiquita Reservoir at Cañada Chiquita in Rancho Santa Margarita, Orange County. Over 91 m of Sespe Formation were exposed during grading at the construction site in a small east draining tributary canyon along the west side of Cañada Chiquita (Figure 1). A small sample of isolated mammal teeth was recovered from a silty claystone bed near the base of the exposed section by wet screen sieving of over 2,722 kg (6000-pounds) of bulk matrix, followed by heavy liquid separation of the fossils from the resulting concentrate. Due to subsequent construction, the locality has been graded away. The purpose of this report is to document the taxa represented in the sample.

## METHODS

All specimens described herein are contained in the collection of the Department of Paleontology at the San Diego Museum of Natural History (SDSNH). Detailed locality data are available at that institution. The sampling site has been designated as SDSNH locality 6408 (Figure 1). Upper teeth and lower teeth are designated by uppercase and lowercase letters, respectively. Dental terminology follows White (1991) for leporids, Korth and Branciforte (2007) for geomyoids, and Korth (1994) for sciurids and cricetids. Dental formulae follow standard usage (e.g, Korth 1994). Tooth measurements were made with an optical micrometer to the nearest 0.01 mm. North American Land Mammal ages and their subbiozones follow Tedford et al. (2004) and Janis et al. (2008), with the Arikareean subbiozones Ar-2 and Ar-3 modified following Albright et al. (2008).

Abbreviations and acronyms are as follows: ap, greatest anteroposterior length; GPTS, Geomagnetic Polarity Time Scale; L, left; LF, local fauna; LACM, Department of Vertebrate Paleontology, Natural History Museum of Los Angeles County; Ma, megannum in the radioisotopic time scale; R, right; SDSNH, Department of Paleontology, San Diego Museum of Natural History; S/V, undifferentiated Sespe and Vaqueros formations; tra, anterior transverse width; trp, posterior transverse width.

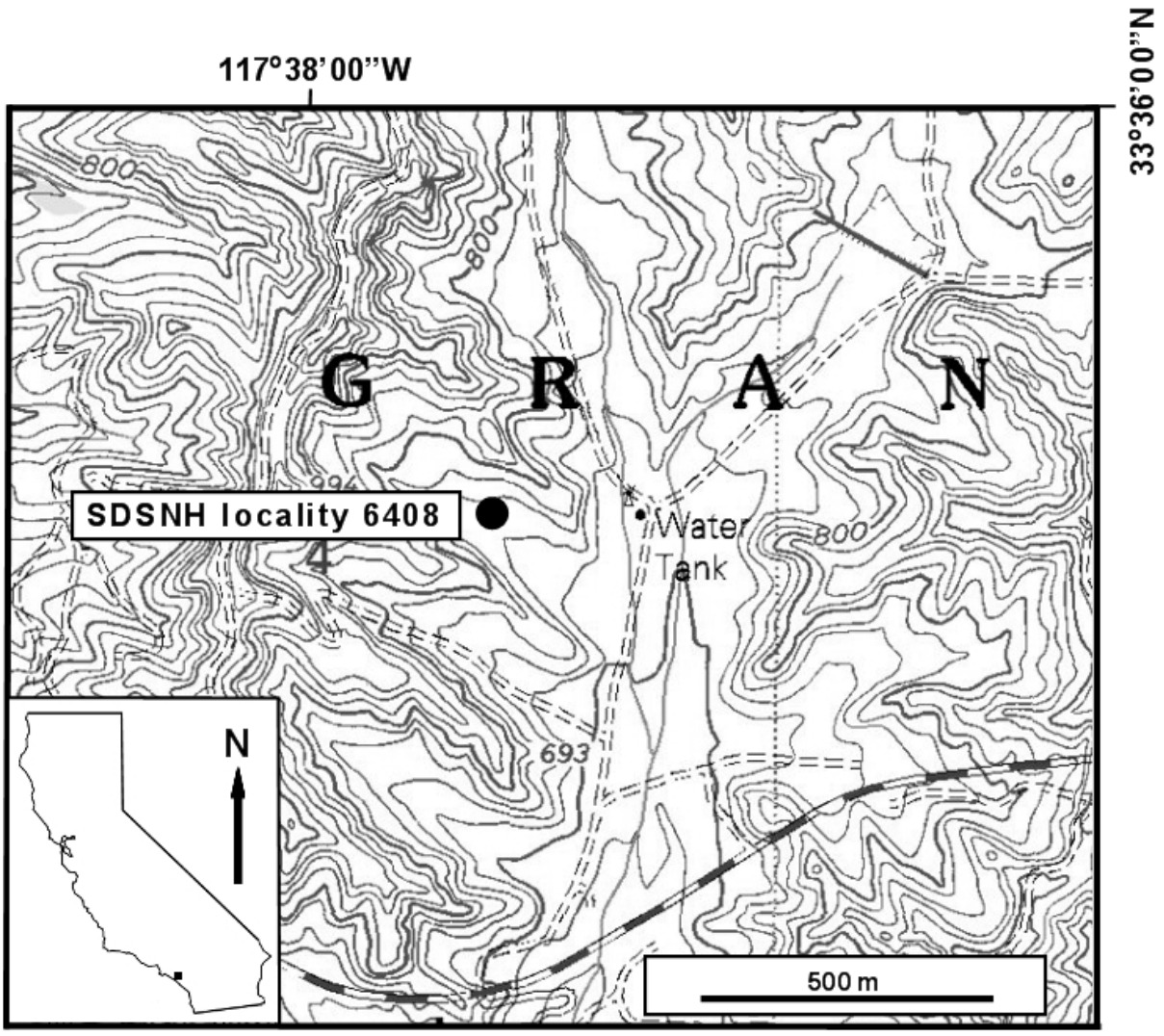


FIGURE 1. Map showing geographic location of SDSNH locality 6408 in Cañada Chiquita, Orange County that yielded the Cañada Chiquita LF and insert map showing location in California. Base topographic map, U.S. Geological Survey, Cañada Gobernadora 7.5 minute quadrangle, scale = 1:24,000.

SYSTEMATIC PALEONTOLOGY
Class Mammalia Linnaeus, 1758
Order Soricomorpha Gregory, 1910
Family Soricidae Fischer de Waldheim, 1817
Subfamily Heterosoricinae Viret and Zapfe, 1951
heterosoricine, gen. and sp. undetermined

**Specimen—**partial left upper incisor, SDSNH 127046.

**Discussion—**The crown of the upper incisor from the Sespe Formation (Figure 2) is missing the anterior distal portion of the apex. The root extends posteriorly from the crown and then bends slightly ventrally near its base. Even though the tip of the crown is missing, it is clear that the apex was curved medially and narrower than the base of the crown (Figure 2B). The labial cingulum is moderately well developed and a distinct cusp is present along the ventral edge between the apex and the base of the crown.

The morphology of the upper incisor is most similar to those of the Heterosoricinae, but a more definitive diagnosis cannot be made without more complete material. However, the specimen does indicate the presence of an undetermined heterosoricine lipotyphlan at Cañada Chiquita.

Order Lagomorpha Brandt, 1855
Family Leporidae Gray, 1821
Genus *Archaeolagus* Dice, 1917
*Archaeolagus* sp.

**Specimens—**RM1 or 2, SDSNH 127047; partial RM1 or 2, SDSNH 127048; partial Lm1 or 2, SDSNH 127049.

**Discussion—** The Leporidae are represented in the Sespe Formation by an upper molar (Figure 3A), a partial upper molar, and a partial lower molar. These teeth are typical of those in *Archaeolagus*, including upper molars displaying straight-walled reentrant valleys and weakly developed fossettes (Dice, 1917, 1929; Dawson, 1958, 2008). Measurements of SDSNH 127047 are ap = 1.56 mm, tra = 2.84 mm, and trp = 2.43 mm.


FIGURE 2. Hetersoricine lipotyphlan, genus undetermined from Cañada Chiquita LF, partial left upper incisor, SDSNH 127046. A, lateral view. B, occlusal view. Scale = 1 mm.

Order Rodentia Bowdich, 1821
Family Sciuridae Gray, 1821
Genus *Nototamias* Pratt and Morgan, 1989
*Nototamias* sp.

**Specimen—**Rp4, SDSNH 127050.

**Discussion—**The p4 (SDSNH 127050, Figure 3B) from the Sespe Formation is indistinguishable from those of the small chipmunk *Nototamias*, including the following shared diagnostic dental characters (Pratt and Morgan, 1989): 1) a small trigonid basin with the protoconid and metaconid closely appressed; 2) an indistinct entoconid; 3) a complete hypolophid; 4) absence of a mesoconid and metastylid; and 5) small size. Measurements of SDSNH 127050 are ap = 1.05 mm, tra = 0.64 mm, and trp = 0.80 mm.

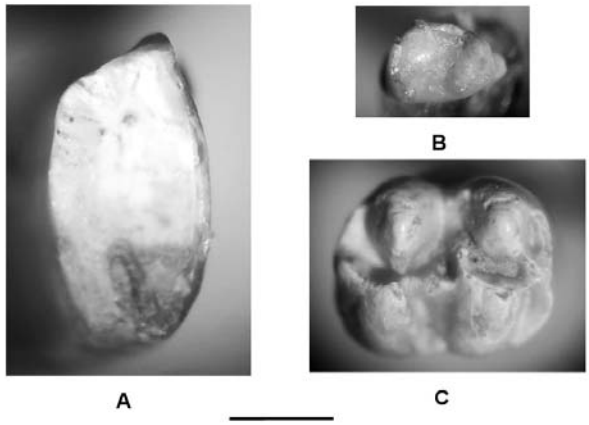


FIGURE 3. Leporidae, Cricetidae, and Sciuridae from Cañada Chiquita LF. A, *Archaeolagus* sp., SDSNH 127047. B, *Nototamias* sp., Rp4, SDSNH 127050. C, *Leidymys nematodon*, Rm2, SDSNH 127158. All occlusal views. Scale = 1 mm.

Family Heliscomyidae Korth, Wahlert, and Emry, 1991
Genus *Heliscomys* Cope, 1873
*Heliscomys* sp.

**Specimens—**LM1 or 2, SDSNH 127098; LM1 or 2, SDSNH 127099; LM1 or 2, SDSNH 127100; LM3, SDSNH 127101; Rm1 or 2, SDSNH 127104; Lm1 or 2, SDSNH 127102; Lm1or 2, SDSNH 127103.

**Discussion—**The dental morphology of *Heliscomys* has been thoroughly described in the literature and most species are diagnosed based primarily on their premolar occlusal morphologies and the sizes of the premolars relative to those of the molars (e.g., Korth, 1989; Korth et al., 1991; Korth, 1994; Korth, 2007; Kelly, 2009). The seven referred teeth from the Sespe Formation (Figure 4) exhibit characters typical of those of *Heliscomys* and are confidently assigned to the genus. *Heliscomys* sp. from Cañada Chiquita is similar in size to *H. walshi* Kelly 2009, slightly smaller than *H. vetus* Cope, 1873, *H. subtilus* (Lindsay, 1972), *H. ostranderi* Korth et al., 1991, and *H. macdonaldi* Korth and Branchiforte 2007, and significantly smaller than *H. gregoryi* Wood, 1933, *H. hatcheri* Wood, 1935, *H. senex* Wood, 1935, and *H. medius* Korth, 2007. The upper molars of the Cañada Chiquita *Heliscomys* sp. are similar to those of the Chadronian *H. ostranderi* and latest Whitneyan or earliest Arikareean *H. medius* in having anterior and

lingual cingula that form a relatively continuous ridge from the paracone to the hypocone (Korth et al., 1991; Korth, 2007). They exhibit further similarity to those of *H. medius* by having a reduced and laterally compressed protostyle that is smaller than the entostyle (Korth, 2007). The *Heliscomys* specimens from Cañada Chiquita probably represent a new species, but without much more complete material, including upper and lower premolars, they are regarded herein as an undetermined species of the genus. Measurements of the teeth of *Heliscomys* sp. are presented in Table 1.

TABLE 1. Measurements (in mm) of teeth of *Heliscomys* sp. from Cañada Chiquita LF.

| SDSNH Number | Tooth/position | ap | tra | trp |
|---|---|---|---|---|
| 127098 | LM1 or 2 | 0.70 | 0.86 | 0.81 |
| 127099 | LM1 or 2 | 0.70 | 0.87 | 0.80 |
| 127100 | LM1 or 2 | 0.74 | 0.81 | 0.73 |
| 127101 | LM3 | 0.54 | 0.72 | 0.56 |
| 127104 | Rm1 or 2 | 0.86 | 0.76 | 0.79 |
| 127102 | Lm1 or 2 | 0.84 | 0.76 | 0.75 |
| 127103 | Lm1 or 2 | 0.85 | 0.77 | 0.73 |

Family ?Geomyidae Gill, 1872
Genus *Tenudomys* Rensberger, 1973
*Tenudomys* sp.

**Specimens—**RM1 or 2, SDSNH 127056; RM1 or 2, SDSNH 127057; Lm1 or 2, SDSNH 127058.

**Discussion—**The Geomyoidea (?Geomyidae) are represented in the sample from the Sespe Formation by three molars referred to *Tenudomys* (Figure 5F-H). Additional molar fragments in the sample might also represent *Tenudomys* (e.g., SDSNH 127059-127064). Korth (1993) and Korth and Branciforte (2007) provided the most recent reviews of *Tenudomys*. The SDSNH specimens exhibit the following shared dental characters with *Tenudomys*: 1) the m1-2 metalophid is widely separated from the hypolophid; 2) the m1-2 protostylids are expanded posteriorly, more so than those of *Schizodontomys* Rensberger, 1973, and *Pleurolicus* Cope, 1878 (Korth, 1996); and 3) the M1-2 have a complete lingual cingulum that is not interrupted by central transverse valley, a metaloph that is separated from the lingual cingulum by a valley, and a lingual cingulum that lacks distinct stylar cusps. The teeth of the *Tenudomys* specimens from the Sespe Formation are slightly larger than those *Tenudomys ridgeviewensis* Korth and Branciforte, 2007, slightly smaller than those of *T. macdonaldi* Rensberger, 1973, but similar in size to those of *T. bodei* (Wilson, 1949). Measurements of the teeth of the SDSNH specimens of *Tenudomys* sp. are presented in Table 2.

TABLE 2. Measurements (in mm) of teeth of *Tenudomys* sp. from Cañada Chiquita LF.

| SDSNH Number | Tooth/position | ap | tra | trp |
|---|---|---|---|---|
| 127056 | RM1 or 2 | 1.54 | 1.80 | 1.91 |
| 127057 | RM1 or 2 | 1.33 | 1.65 | 1.69 |
| 127058 | Lm1 or 2 | 1.45 | 1.72 | 1.59 |

Family Heteromyidae Gray, 1868
Genus *Proharrymys* Korth and Branciforte, 2007
cf. *Proharrymys* sp.

**Specimens—**LP4, SDSNH 127053; partial LM1 or 2, SDSNH 127148; Lp4, SDSNH 127151; partial Ldp4 or Lp4, SDSNH 127149.

**Description—**The P4 (SDSNH 127053) has a simple protoloph that consists of a large protocone, but no protostyle (Figure 5I). On the anterolabial slope of the protocone is a very small cuspule, which may represent a paracone. In *Proharrymys walherti*, Korth and Branciforte (2007) reported that a small paracone is present on 17% of the P4 specimens. The metaloph consists of three cusps; the metacone, hypocone, and hypostyle. A posterior cingulum is present, posterior to the metaloph, that extends from the posterolabial corner of the metacone to the posterolingual corner of the hypocone.

The partial LM1 or 2 is missing the anterior most portion of the anterior cingulum and the labial half of the tooth (Figure 5J). A protostyle or hypostyle are completely lacking along the continuous crest or cingulum, which closes off the central transverse valley lingually. In the *Proharrymys*, the M1-2 have a continuous lingual cingulum (not interrupted by the central transverse valley) and lack stylar cusps, except for a weakly developed hypostyle on M1 (Korth and Branciforte, 2007).

The two p4s (Figure 5K-L) from the Sespe Formation have metalophids that are narrower than the hypolophids, reduced protostylids, and well-developed hypoconulids. The p4 (SDSNH 127151) has a low, but distinct, central lophid that connects the metaconid to the anterolabial corner of the entoconid (Figure 5K), similar to those of *Proharrymys* (Korth and Branciforte, 2007, see fig. 5b). The other p4 (SDSNH 127149), which might be a deciduous tooth, is broken and missing the lingual edges of the anterior cingulid and protostylid (Figure 5L). However, from the remaining intact edge of the protostylid, it is clear that this cusp was reduced in size relative to the protoconid. A distinct central lophid is present in SDSNH 127149 that connects the metaconid to the hypolophid, somewhat similar to those of *Proharrymys* (see Korth and Branciforte, 2007, fig. 5c). Korth and Branciforte (2007) noted that the p4 central lophid of *Proharrymys fedti* (Macdonald, 1963) is variable in height and, in

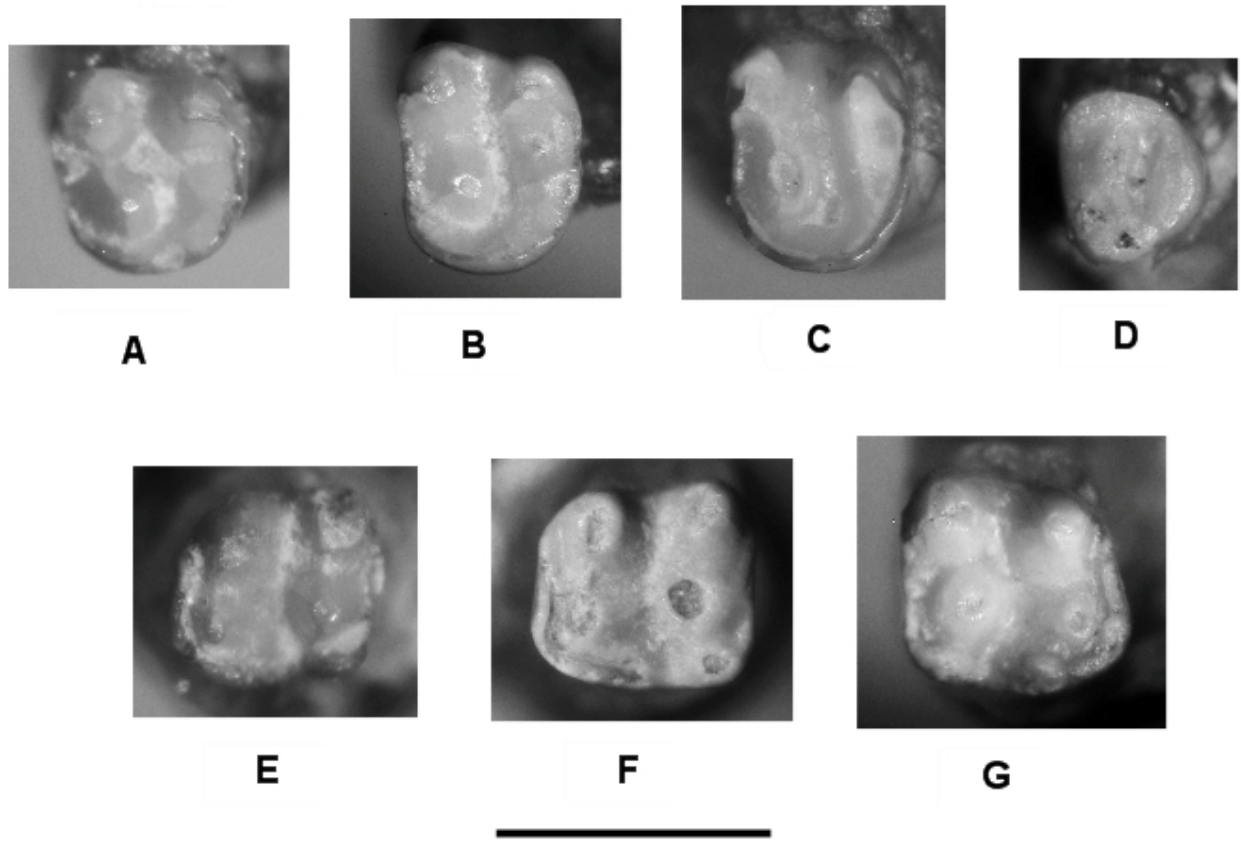


FIGURE 4. *Heliscomys* sp. from Cañada Chiquita LF, A, LM1 or 2, SDSNH 127100; B, LM1 or 2, SDSNH 127099; C, LM1 or 2, SDSNH 127098; D, LM3, SDSNH 127101; E, Lm1 or 2, SDSNH 127103; F, Lm1 or 2, SDSNH 127102; G, Rm1 or 2, SDSNH 127104. All occlusal views. Scale = 1 mm.

some specimens, ends in the valley between the metalophid and hypolophid and does not reach the entoconid.

Measurements of the teeth of cf. *Proharrymys* sp. from the Sespe Formation are presented in Table 3.

TABLE 3. Measurements (in mm) of cf. *Proharrymys* sp. from Cañada Chiquita LF.

| SDSNH Number | Tooth/position | ap | tra | trp |
|---|---|---|---|---|
| 127053 | LP4 | 0.83 | 0.59 | 0.82 |
| 127151 | Lp4 | 1.04 | 0.77 | 0.87 |
| 127149 | Ldp4 or Lp4 | 0.84 | — | 0.82 |
| 127054 | Rm3 | 0.75 | 0.77 | 0.63 |

**Discussion—**Overall, the five referred teeth from the Sespe Formation share the following dental characters with *Proharrymys* (Macdonald, 1963; Korth and Branciforte, 2007; Korth, 2008a): 1) the p4s have a reduced protostylid, a V-shaped hypolophid, a central lophid connecting the metaconid to the entoconid or hypolophid, and a well-developed hypoconulid; 2) the P4 has a large protocone and a posterior cingulum that extends from the metacone to the hypocone; and 3) an upper molar with a complete lingual cingulum that lacks stylar cusps.

However, it must be noted that assigning isolated teeth to certain genera and species of the Geomorpha Thaler, 1966, without intact upper and lower dentitions for comparison and/or knowledge of the cranial morphology can be a difficult task. Good examples of this are the changing taxonomic status that occurs when new material becomes available for species that were previously known only from a single specimen or only a few specimens and sometimes represented only by an upper or lower dentition. For example, Wood (1937) named a new species of heteromyid, *Proheteromys nebraskensis*, based on two dentaries with lower dentitions from the Whitneyan of Nebraska. Black (1961a) named *Heliscomys schlaikjeri* based on a single specimen with P4-M2 from the Arikareean of

Wyoming. Walhert (1984) erected a new genus of florentiamyid, *Kirkomys*, the type species being *K. milleri* from the Whitneyan of Nebraska, which was known only from a partial skull with a complete upper dentition. Walhert (1984) noted that Black's specimen of *H. schlaikjeri* exhibited certain dental characters in common with *K. milleri* and assigned it to his new genus. Based on a much larger sample from the early Arikareean Ridgeview LF of Nebraska, including upper and lower teeth, Korth and Branciforte (2007) recognized that specimens originally referred to *P. nebraskensis* by Wood (1937) actually represented the lower dentitions of *K. milleri* and, in a new combination with synonymy, referred *K. milleri* and *P. nebraskensis* to *Kirkomys nebraskensis*. Also, based on a sample of upper and lower dentitions from the Ridgeview LF, Korth and Branciforte (2007) named a new genus of heteromyid, *Proharrymys*, with *P. walherti* designated as the type species. Korth and Branciforte (2007, p. 197) then, in a new combination based primarily on the shared presence of a posterior cingulum on the P4, referred *K. schlaikjeri* to their new genus as *Proharrymys schlaikjeri*. Most recently, Korth (2008a) revaluated the taxonomic status of *Diplolophus parvus* Troxell, 1923, (= *Proheteromys parvus* vide Wood, 1935) and in a new combination referred it to *Kirkomys*. Korth (2008b) described a sample of upper and lower dentitions of *K. parvus* from the latest Whitneyan or earliest Arikareean Blue Ash LF of Nebraska, which included P4s with posterior cingula. With the new sample of *K. parvus* for comparison, Korth (2008b) re-evaluated the referral of *K. schlaikjeri* to *Proharrymys* and considered that Walhert's (1984) original assignment of this taxon to *Kirkomys* may be correct. In summary, based often on minor differences in occlusal morphology and the ongoing discovery of new material, the above taxa have been assigned and reassigned to different genera encompassing three families of the Geomorpha.

Because of the very small sample size, fragmentary nature of the specimens and the taxonomic uncertainties that have previously occurred for certain members of the Geomorpha, confident generic assignment of the four teeth from the Sespe Formation cannot be made, but because they do exhibit certain dental similarities to those of *Proharrymys*, are herein referred to as cf. *Proharrymys* sp.

Genus *Proheteromys* Wood, 1932
*Proheteromys* sp.

**Specimens—**LP4, SDSNH 127110; partial LP4, SDSNH 127111; RM1 or 2, SDSNH 127105; partial RM1 or 2, SDSNH 127106; partial RM1 or 2, SDSNH 127107; partial RM1 or 2, SDSNH 127108; partial LM1 or 2, SDSNH 127112; partial LM1 or 2, SDSNH 127113; partial M1 or 2, SDSNH 127115; RM3, SDSNH 127109; partial LM3, SDSNH 127114; Rp4, SDSNH 127116; partial Rp4, SDSNH 127117; Lp4, SDSNH 127127; partial p4, SDSNH 127143; Rm1 or 2, SDSNH 127118; partial Rm1 or 2, SDSNH 127119; partial Rm1 or 2, SDSNH 127120; partial Rm1 or 2, SDSNH 127121; partial Rm1 or 2, SDSNH 127122; partial Rm1 or 2, SDSNH 127123; partial Rm1 or 2, SDSNH 127124; partial Rm1 or 2, SDSNH 127125; partial Rm1 or 2, SDSNH 127126; Lm1 or 2, SDSNH 127128; Lm1 or 2, SDSNH 127129; Lm1 or 2, SDSNH 127130; Lm1 or 2, SDSNH 127131; Lm1 or 2, SDSNH 127132; partial Lm1 or 2, SDSNH 127133; partial Lm1 or 2, SDSNH 127134; partial Lm1 or 2, SDSNH 127135; partial Lm1 or 2, SDSNH 127136; partial Lm1 or 2, SDSNH 127137; partial Lm1 or 2, SDSNH 12738; partial Lm1 or 2, SDSNH 127139; partial Lm1 or 2, SDSNH 127140; partial Lm1 or 2, SDSNH 127141; partial Lm1 or 2, SDSNH 127142;

**Discussion—**A medium-sized species of *Proheteromys* (Figure 6) is the most common taxon in the Cañada Chiquita LF and is characterized by the following dental characters: 1) the P4 protoloph has a well-developed protocone and slightly smaller paracone; 2) the P4 has a small cusp (protostyle) positioned anteriorly to the protocone; 3) the M1 or 2 has an incomplete lingual cingulum that is interrupted by the central transverse valley and distinct stylar cusps; 4) the p4 has four distinct primary cusps (metalophid consisting of the metaconid and protostylid and hypolophid consisting of the entoconid and hypoconid), a small, distinct posterior cingulum, and lacking a central lophid between the metalophid and hypolophid; and 5) m1-2 mesodont and bilophate with wide transverse valleys, moderately distinct primary cusps, and well-developed stylar cusps. Measurements of the teeth of *Proheteromys* sp. from the Sespe Formation are presented in Table 4.

TABLE 4. Measurements (in mm) of teeth of *Proheteromys* sp. from Cañada Chiquita LF.

| SDSNH Number | Tooth/position | ap | tra | trp |
|---|---|---|---|---|
| 127110 | LP4 | 1.35 | 0.90 | 1.37 |
| 127105 | RM1 or 2 | 1.05 | 1.49 | 1.47 |
| 127109 | RM3 | 0.72 | 0.98 | 0.80 |
| 127114 | partial LM3 | 0.80 | 0.99 | — |
| 127127 | Lp4 | 0.86 | 0.67 | 0.93 |
| 127116 | Rp4 | 0.92 | 0.58 | 1.04 |
| 127120 | Lm1 or 2 | 1.15 | 1.36 | 1.18 |
| 127128 | Lm1 or 2 | 1.30 | 1.37 | 1.39 |
| 127130 | Lm1 or2 | 1.12 | 1.30 | 1.25 |
| 127131 | Lm1 or 2 | 1.13 | 1.30 | 1.33 |
| 127132 | Lm1 or 2 | 1.03 | 1.31 | 1.21 |
| 127118 | Rm1 or 2 | 1.06 | 1.37 | 1.26 |

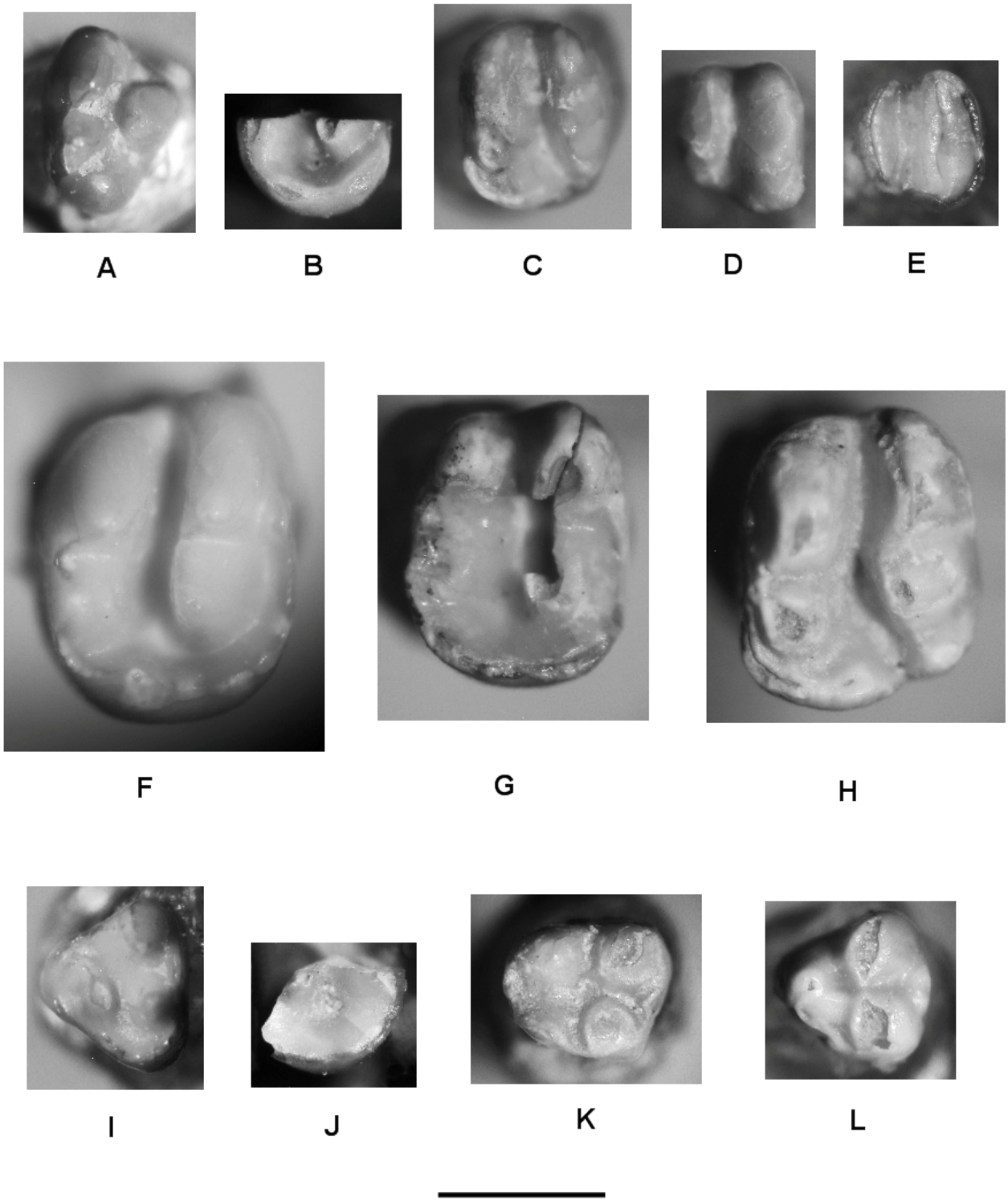


FIGURE 5. Geomyoid and heteromyid rodents from Cañada Chiquita LF. A-E, cf. *Kirkomys* sp., A, RP4, SDSNH 127147; B, partial RM1 or 2, SDSNH 127052; C, Lm1 or 2, SDSNH 127055; D, Rm3, SDSNH 127150; E, Rm3, SDSNH 127054. F-H, *Tenudomys* sp., F, RM1 or 2, SDSNH 127056; G, RM1 or 2, SDSNH 127057; H, Lm1 or 2, SDSNH 127058. I-L, cf. *Proharrymys* sp., I, LP4, SDSNH 127053; J, partial LM1 or 2, SDSNH 127148; K, Lp4, SDSNH 127151; L, partial ?Ldp4 or Lp4, SDSNH 127149. All occlusal views. Scale = 1 mm.

Family Florentiamyidae Wood, 1936
Genus *Kirkomys* Wahlert, 1984
cf. *Kirkomys* sp.

**Specimens—**RP4, SDSNH 127147; partial RM1 or 2, SDSNH 127052; Lm1 or 2, SDSNH 127055; Rm3, SDSNH 127050; Rm3, SDSNH 127154.

**Description—**The P4 (SDSNH 127147) protoloph consists of a large protocone that is positioned slightly lingually from the center of the tooth (Figure 5A). The metaloph consists of three cusps; metacone, hypocone , and hypostyle. The metacone and hypocone are positioned relatively close to each other and separated by a moderate valley on the metaloph. The hypostyle is smaller than the metacone and hypocone and is separated from the hypocone by a valley that is deeper and wider than the valley between the metacone and hypocone. The overall occlusal outline appears transversely expanded because the anteroposterior dimension is relatively short as compared with the transverse dimension (ap = 71% of trp), which distinguishes it from the other two P4s from the Sespe Formation. It further differs from SDSNH 127053 (P4 referred above to cf. *Proharrymys* sp.) by having a relatively smaller hypostyle and lacking a posterior cingulum and from SDSNH 127110 (P4 referred above to *Proheteromys* sp.) by its relatively smaller hypostyle, smaller size, and lack of a protostyle and paracone. In *Kirkomys nebraskensis* (Wood, 1937), the P4 is also four cusped with a large protocone and the anteroposterior dimension is moderately short relative to the transverse dimension (mean ap = 88% of mean trp) (see Walhert, 1984, fig. 4; Korth and Branciforte, 2007, fig. 5 and tab. 5).

The partial RM1 or 2 has the linqual half of the tooth missing (Figure 5B). The protocone is separated from the weakly-developed protostyle by a valley. The anterior cingulum is tall and connected to the protostyle. The protostyle and the hypostyle are connected by a tall, complete crest (lingual cingulum), closing off the central transverse valley. The hypostyle is a moderately developed and laterally compressed cusp that is connected to the lingual corner of the hypocone by a tall crest. Together, these cusps and cingula form a continuous, uninterrupted crest that extends from the hypocone to the anteromedial edge of the tooth, anterior to the protocone.

The Lm1 or 2 (SDSNH 127055) has four primary cusps arranged in two transverse lophids (Figure 5C); the metalophid consisting of the protoconid and metaconid, and the hypolophid consisting of the entoconid and hypoconid. The anterior cingulum extends from the anterolabial corner of the tooth to a well-developed protostylid. A well-developed hypostylid is present at the posterolabial corner of the tooth. A deep transverse valley extends across the tooth and is open both labially and lingually. Although the valley is deep, it is slightly less deep near the center of the tooth.

The two m3s (Figure 5 D-E) are similar to the m1 or 2 except for the following: 1) the anterior cingulid is slightly less developed; 2) the width of the hypolophid is more reduced relative to the width of the metalophid; and 3) smaller size. Measurements of the teeth of cf. *Kirkomys* sp. from the Sespe Formation are presented in Table 5.

TABLE 5. Measurements (in mm) of cf. *Kirkomys* sp. from Cañada Chiquita LF, e = estimated.

| SDSNH Number | Tooth/position | ap | tra | trp |
|---|---|---|---|---|
| 127147 | RP4 | 0.59 | 0.80 | 1.13 |
| 127052 | partial RM1 or 2 | 0.85e | — | — |
| 127055 | Lm1 or 2 | 0.91 | 1.18 | 1.05 |
| 127150 | Rm3 | 0.78 | 0.80 | 0.72 |

**Discussion—**The five teeth from the Sespe Formation appear to represent the Florentiamyidae. They share the following dental characters with those of the florentiamyid *Kirkomys nebraskensis* (Wahlert, 1984; Korth and Branciforte, 2007; Korth, 2008b): 1) the P4 is four-cusped with a large protocone and is wider than long; 2) the M1 or 2 (SDSNH 127052) has a complete lingual cingulum (not interrupted by the central transverse valley) and moderately to weakly developed stylar cusps (protostyle and hypostyle); 3) the m1 or 2 has a moderately deep transverse valley and a well-developed protostylid and hypostylid; and 4) the m3 also has a moderately deep transverse valley, a moderately developed protostylid and hypostylid, and is smaller than the m1-2. Even though the five teeth from the Sespe Formation exhibit certain dental similarities to *K. nebraskensis*, confident generic assignment cannot be made because of the same reasons noted above for cf. *Proharrymys* sp., and they are herein referred to as cf. *Kirkomys* sp.

Family Cricetidae Rochebrune, 1883
Genus *Leidymys* Wood, 1936
*Leidymys nematodon* (Cope, 1879)

**Specimen—**Rm2, SDSNH 127158.

**Discussion—**The Rm2 (Figure 3C) from the Sespe Formation is the size of those of *Leidymys nematodon* and *L. blacki* (Macdonald, 1963), whereas it is larger than those of *L. parvus* (Sinclair, 1905), *L. alicae* (Black, 1961b), and *L. cerasus* Korth, 1992, *L. korthi* Williams and Storer, 1998, and much smaller than those of *L. lockingtonianus* (Cope, 1881). The

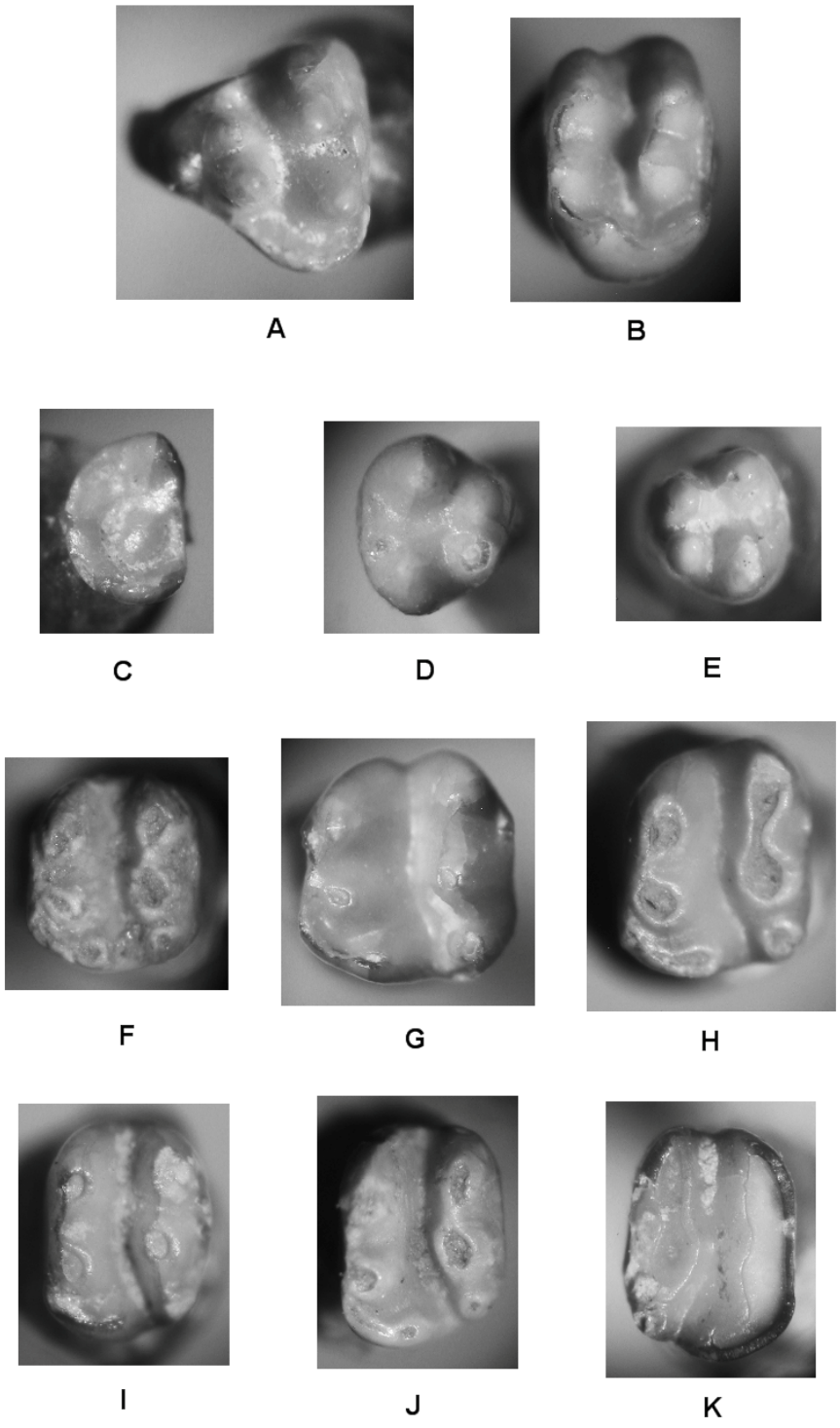


FIGURE 6. *Proheteromys* sp. from Cañada Chiquita LF, A, LP4, SDSNH 127110; B, RM1 or 2, SDSNH 127105; C, RM3, SDSNH 127109; D, Rp4, SDSNH 127116; E, Lp4, SDSNH 127127; F, Lm1 or 2, SDSNH 127130; G, Lm1 or 2, SDSNH 127128; H, Lm1 or 2, SDSNH 127131; I, Lm1 or 2, SDSNH 127132; J, Lm1 or 2, SDSNH 127120; K, Rm1 or 2, SDSNH 127118. All occlusal views. Scale = 1 mm.

Rm2 is indistinguishable from those of *L. nematodon* from the John Day Formation of Oregon, including the following dental characters (Wood, 1936; Martin, 1980): 1) the primary cusps are stepped and distinct; 2) the connection of the metalophulid I to the metaconid and protoconid is positioned anteriorly; 3) the mesoconid is moderately developed; 4) the mesolophid is short and extends anterolingually to join the posterior arm of the protoconid forming a pit or valley between these lophids; and 5) the hypolophid is large and confluent with the hypoconid. It differs from the m2 of the similar sized *L. blacki* from the Sharps Formation of South Dakota (Macdonald, 1963, 1970; Martin, 1980) by having the following: 1) the primary cusps are more distinct, less lophate; 2) the anterior cingulid is less transversely expanded; 3) the mesolophid does not join with the metaconid to form a fossette; and 4) and the mesoconid is less developed and lacks a distinct, labially directed ridge. Measurements of SDSNH 127158 are ap = 2.06 mm, tra = 1.69 mm, and trp = 1.67 mm.

Order Artiodactyla Owen, 1848
Family undetermined

**Specimen—**cheek tooth fragment, SDSNH 127164.

**Discussion—**SDSNH 127164 from the Sespe Formation can only be identified as an artiodactyl cheek tooth fragment.

## CONCLUSIONS

The sample of small mammal fossils from the upper part of the Sespe Formation in Cañada Chiquita is herein referred to the Cañada Chiquita Local Fauna and includes the following taxa: an indeterminate heterosoricine lipotyphlan, *Archaeolagus* sp., *Nototamias* sp., *Heliscomys* sp., *Tenudomys* sp., *Proheteromys* sp., cf. *Kirkomys* sp., cf. *Proharrymys* sp., *Leidymys nematodon*, and an indeterminate artiodactyl.

*Leidymys nematodon* is restricted to the Arikareean upper portions of the Sespe Formation and S/V in Orange County (Whistler and Lander, 2003). The species has also been recorded from several other early to late Arikareean faunas of southern California (Walsh and Deméré, 1991; Korth, 1994; Whistler and Lander, 2003; Wang et al., 2009; Lander, 2011). *Nototamias* and *Proheteromys* have been previously recorded from the Arikareean and early Hemingfordian upper portions of the Sespe Formation and S/V in Orange County (Whistler and Lander, 2003; Wang et al., 2009; Lander, 2011). *Nototamias* has been recorded from the early Arikareean to the early Hemphillian elsewhere in North America, whereas *Proheteromys* is known from the early Whitneyan to late Barstovian (e.g., Flynn et al., 2008; Goodwin, 2008; Wang et al., 2009; Lander, 2011). Previously, *Heliscomys* was recorded only from the early Arikareean Lower Bowerman Landfill LF in the upper part of the S/V in Orange County (Whistler and Lander, 2003). However, the genus is known elsewhere in North America from the Duchesnean to early late Barstovian (Korth et al., 1991; Korth, 1994; Flynn et al., 2008; Kelly, 2009). *Tenudomys* has not been previously recorded from the Sespe Formation or S/V in Orange County, but the genus has been documented in the early Arikareean South Mountain Fauna of the upper part of the Sespe Formation in Ventura County, California (Wilson, 1949; Korth, 1993). *Archaeolagus* has been previously recognized in the early Hemingfordian Santiago Canyon LF of the Upper Orange County S/V Fauna in the upper part of the S/V (Whistler and Lander, 2003), but it is known elsewhere in North America from possibly as early as the early Orellan to late Hemingfordian (Dawson, 2008). The Heterosoricinae have been previously recorded from the Arikareean and early Hemingfordian upper part of the S/Vin the Orange County (Whistler and Lander, 2003).

The two most age-diagnostic rodents of the Cañada Chiquita LF are *Leidymys nematodon* and *Tenudomys* sp. (Figure 7). In the John Day Formation of Oregon, *L. nematodon* is restricted from unit K1 of the Turtle Cove Member to unit M of the Kimberly Member, which, based on new radioisotopic dating and magnetostratigraphic correlation, spans Chrons C9n to C7n.2 of the GPTS, or about 27.9 to 24.1 Ma (Albright et al., 2008; Fremd and Whistler, 2009). Albright et al. (2008) correlate this interval with Ar-2 and part of Ar-3 of the subbiozones of the Arikareean. *Leidymys nematodon* has been recorded in the Alamos Canyon LF of the Sespe Formation, which Prothero et al. (1996) placed within Chron C9r dated between 28.2 to 27.9 Ma and the Blakeley LF of Sespe Formation, which Lander (2000, p. 36) and Lander and Whistler (2003) regarded as early Arikareean in age or about 28.2 to 27.9 Ma. Whistler and Lander (2003) recorded *L. nematodon* from several other faunas of Arikareean age (Ar-1 to Ar-4) from the Sespe Formation and the S/V of southern California that they considered to date from about 30.0 to 18.8 Ma.

*Tenudomys* is recorded only in faunas of early Orellan to early late Arikareean age (Or-1 to Ar-3, or about 33.7-22.8 Ma) (Wilson, 1949; Rensberger, 1973; Korth, 1993, 1994; Korth and Branciforte, 2007; Albright et al., 2008; Flynn et al., 2008). The occurrences of these two taxa in the Cañada Chiquita LF suggest that the age of the assemblage could range anywhere from the early to early late Arikareean (Ar-1

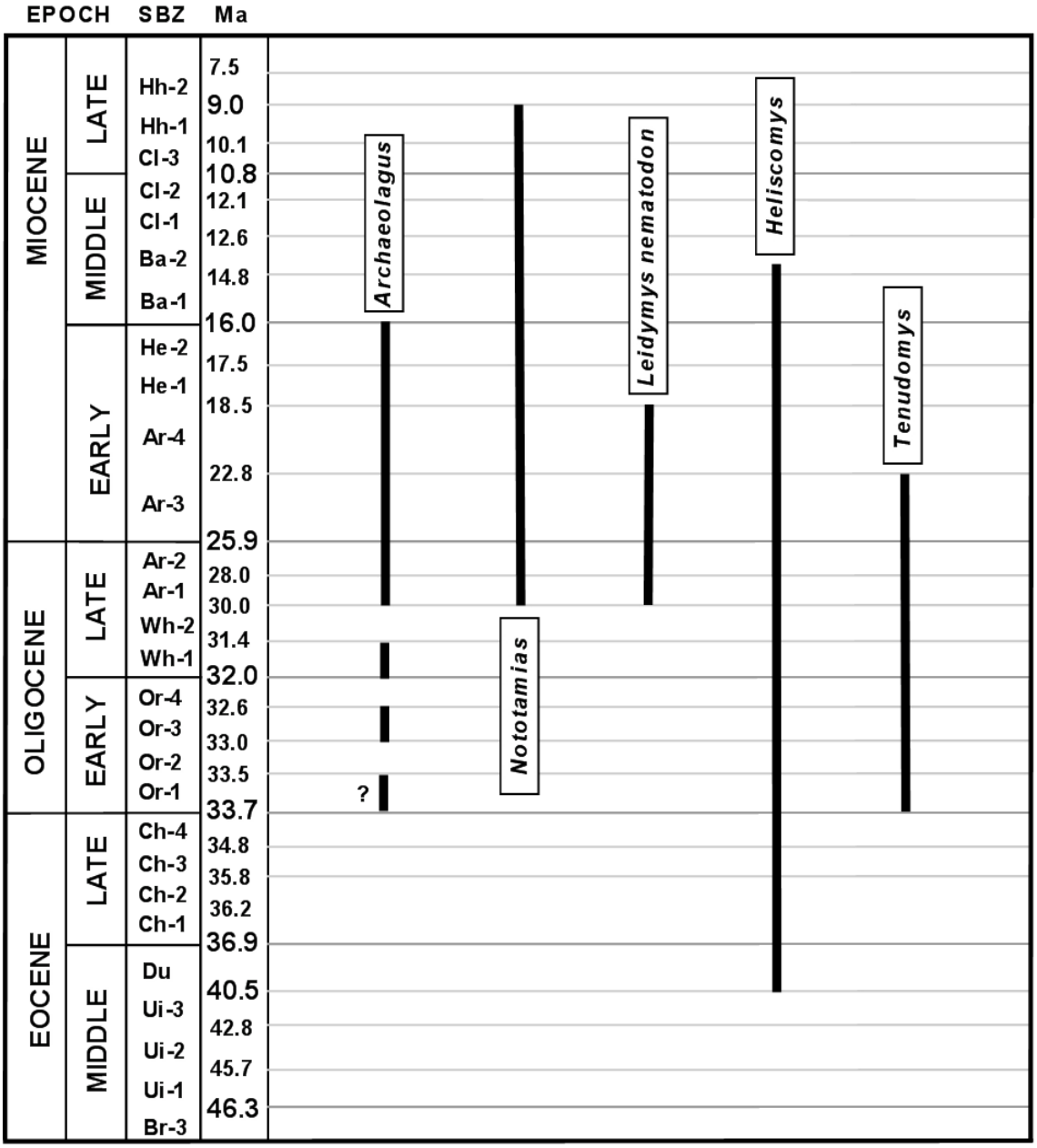


FIGURE 7. Recorded North American subbiozone ranges (thick vertical lines) of genera and species discussed in text. Abbreviations are: Ar, Arikareean; Ba, Barstovian; Br, Bridgerian; Ch, Chadronian; Cl, Clarendonian; Du, Duchesnean; He, Hemingfordian; Hh, Hemphillian; Ma, megannum in the radioisotopic time scale; Or, Orellan; SBZ, subbiozones of the North American Land Mammal ages (after Tedford et al., 2004 and Janis et al., 2008, with Ar-2 and Ar-3 modified following Albright et al., 2008); Ui, Uintan; Wh, Whitneyan. Subbiozones Hh-2 and Br-3 extend younger and older, respectively, than shown in SBZ column.

to Ar-3, or about 30.0-22.8 Ma). Although cf. *Kirkomys* sp. and cf. *Proharrymys* sp. of the Cañada Chiquita LF share certain dental characters with those *Kirkomys* and *Proharrymys*, respectively, these taxa are not characterized well enough for definitive generic assignments and, therefore, are regarded as unreliable age-diagnostic taxa. All the other small mammal genera indentified in the Cañada Chiquita LF do not provide any additional age restrictions for the fauna (Figure 7).

Based primarily on the co-occurrence of *Leidymys nematodon* and *Tenudomys* in the Cañada Chiquita LF,

the assemblage is Arikareean in age, possibly early to early late Arikareean. New records for the Arikareean of the Sespe Formation and S/V in the Orange County are *Archaeolagus* sp., *Tenudomys* sp., cf. *Kirkomys* sp., and cf. *Proharrymys* sp.

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