

## NEW RECORDS OF MULTITUBERCULATE MAMMALS FROM THE GOLER FORMATION (TIFFANIAN, PALEOCENE) OF CALIFORNIA

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### ABSTRACT

New records of multituberculates (*Neoliotomus conventus*, *Golercosmodon mylesi*, and an unidentified microcosmodontid) are added to the assemblage of late Paleocene mammals from member 4 of the Goler Formation of California. Multituberculate incisors recovered in the 1950s were questionably identified as *Neoliotomus*, but a recently collected P4 confirms the presence of *Neoliotomus conventus* in the Goler Formation. *Golercosmodon mylesi* is a new genus and species of microcosmodontid based on isolated P4s which differ from those of all other microcosmodontids in the development of the labial cusp row and in having a greater number of medial row cusps. Twenty-seven microcosmodontid molars recovered from the Goler Formation could not be identified to taxon, but most probably represent *G. mylesi* because 80% of Goler microcosmodontid P4s represent that species. The presence of a second Goler Formation microcosmodontid is confirmed by a heavily worn P4 that is smaller and more squared in occlusal outline than *G. mylesi*. The Goler Formation occurrence of *Neoliotomus conventus* probably predates its late Tiffanian appearance in the Western Interior. The endemic Goler taxon, *Golercosmodon mylesi*, increases the diversity of North American microcosmodontids, and provides additional support for the presence of a discrete Goler faunal province on the west coast of North America during the late Paleocene.

### INTRODUCTION

The Goler Formation outcrops in the El Paso Mountains of the northern Mojave Desert of southern California and consists of about 3000 meters of mostly non-marine strata, subdivided into four members (numbered 1 through 4, with member 4 consisting of four informal subdivisions, referred to as members 4a through 4d, Cox, 1982, 1987; Figure 1). Initial efforts in the 1950s–1980s to recover vertebrate fossils yielded a sparse assemblage of Paleocene mammals from member 4 that included three multituberculate incisors which were tentatively identified to genus (McKenna, 1955, 1960; McKenna et al., 1987). A renewed phase of collecting, beginning in 1993, resulted in recovery of a few hundred mammalian specimens from members 4a and 4b (Lofgren et al., 2002, 2008, 2009, 2014; McKenna and Lofgren, 2003; McKenna et al., 2008; Williamson and Lofgren, 2014), including skulls and isolated teeth of multituberculates.

The eutherian mammalian assemblage from members 4a and 4b of the Goler Formation reflects significant endemism and also indicates that these

strata are middle Tiffanian in age (Ti3–Ti4a) (Lofgren et al., 2014). These specimens and endemic Goler Formation turtles and metatherians indicate that the Goler vertebrate assemblage represents a discrete faunal province on the west coast of North America during the late Paleocene (Hutchison, 2004; Lofgren et al., 2014; Williamson and Lofgren, 2014). Here we identify three multituberculate taxa from the Goler Formation, including a new genus and species, and reassess the age of member 4 and the degree of endemism of the Goler mammalian assemblage.

### MATERIALS, METHODS, ABBREVIATIONS

Multituberculate teeth described here were recovered mainly from screen-washing of the Laudate Discovery Site (RAM locality V94014, member 4a), Edentulous Jaw Site (RAM locality V98012, member 4b), Grand Canyon (RAM locality V200510, member 4a), and Land of Oz (RAM locality V200001, member 4a); surface collection at Goler Canine (RAM locality V94133, member 4a) also yielded two multituberculate incisors (McKenna, 1960). Thirty-three RAM

multituberculate teeth are described, and three previously reported incisors (McKenna, 1960; McKenna et al., 1987) are discussed. Two multituberculate skulls also recovered from the Goler Formation represent a species of *Parectypodus* (RAM 9048; found by M. McKenna) and a larger taxon (RAM 9663; found by J. Honey). These skulls will be described elsewhere utilizing  $\mu$ CT technology.

The classification scheme employed here is that of Kielan-Jaworowska and Hurum (2001) for *Neoliotomus* and Fox (2005) for the Microcosmodontidae. Teeth were measured in mm using a Dino-Lite digital microscope. Upper teeth are represented by capital letters and lower teeth by lower case letters. Institutional abbreviations are as follows: FMNH, Field Museum of Natural History, Chicago, Illinois; PU, Princeton University Collection at Yale University, New Haven, Connecticut; RAM, Raymond Alf Museum of Paleontology, The Webb Schools, Claremont, California; SMM, Science Museum of Minnesota, St Paul, Minnesota; UALVP, University of Alberta Laboratory of Vertebrate Paleontology, Edmonton, Alberta, Canada; UCMP, University of California Museum of Paleontology, Berkeley, California; UM, University of Michigan Museum of Paleontology, Ann Arbor, Michigan; UMVP, University of Minnesota Vertebrate Paleontology, Minneapolis, Minnesota. Other abbreviations: NALMA, North American Land Mammal Age; Ti, Tiffanian NALMA; Ti1, Ti3, Ti4a, Ti5, interval zones of the Tiffanian NALMA; To3, interval zone of the Torrejonian NALMA.

#### SYSTEMATIC PALEONTOLOGY

Order Multituberculata Cope, 1884

?Ptilodontoidea

*Neoliotomus* Jepsen, 1930a

*Neoliotomus conventus* Jepsen, 1930a

(Figures 2, 3, 4)

**Holotype**—PU 13297, left lower jaw fragment with broken i, p4, and root of p3; broken left M1; part of right maxilla with root of P3 and broken P4, and showing base of malar process, Paint Creek locality, Park County, Wyoming (Jepsen, 1930a; plate IV, figs. 6-7).

**Referred Specimens**—UCMP 49490, left lower incisor crown fragment, and UCMP 55399, right lower incisor root with enamel from UCMP locality V5870 (equivalent to RAM locality V94133), both from member 4a of the Goler Formation; RAM 7237, left P4 fragment from RAM locality V98012, member 4b; RAM 7204, heavily damaged right p4 from RAM locality V200001, member 4a, questionable referral.

**Description and Discussion**—These isolated teeth are referred to *Neoliotomus conventus* based

primarily on size, except for RAM 7237, a partial P4, that exhibits the unique crown morphology of the few known P4s of *N. conventus*.

RAM 7237 is a broken P4 that represents the posterior two-thirds of the tooth. It lacks any trace of the roots and its crown is unworn and triangular in cross section. RAM 7237 has nine cusps (eight complete, one partial), each of which (except the most posterior cusp) have well-developed labial and lingual ridges which extend ventrally (Figure 2). As preserved, RAM 7237 has a width of 4.1 mm and a length of 7.1 mm, but its total length is estimated to be 11.5 mm based on comparison to the drawing of a complete P4 (UM 72647) provided by Krause (1980; fig. 9C), if both P4s had the same cusp formula.

RAM 7237 represents the posterior part of the P4 because it lacks an anterior labial cusp which is present on the P4 of the holotype of *Neoliotomus conventus* (PU 13297) (Jepsen, 1930a; plate IV, figs. 6-7) and UM 72647 (Krause, 1980; fig. 9C). The angles of slope for the labial and lingual walls of RAM 7237 are not equal. This is evident in occlusal view because the line of cusps is not positioned on the midline of the tooth (Figure 2). Thus, either the lingual or labial slope is broader in occlusal view. The only reported complete P4 of *N. conventus* (UM 72647) is shown only in labial view (Krause, 1980; fig. 9C), so a comparison of the labial and lingual slopes cannot be made. But in the reconstruction of the upper dentition of *Neoliotomus ultimus* by Krause (1982; fig. 13) the slope of the lingual wall of the P4 appears to be steeper than the labial wall. Thus, RAM 7237 is probably a left P4 and its large size and unique medial row cusp morphology clearly align it with *N. conventus*.

A short report from M. McKenna that two large incisor fragments (UCMP 49490 and UCMP 55399) were recovered in 1958 from the Goler Formation appeared in the February 1959 edition of the Society of Vertebrate Paleontology News Bulletin (Number 55). They were found at UCMP locality 5870, a site in the uppermost part of member 4a (McKenna, 1960; McKenna et al., 1987). The two lower incisor fragments, UCMP 55399 and UCMP 49490, were thoroughly described and figured by McKenna (1960; fig. 2) who stated that the Goler “incisors are almost indistinguishable from incisors of *Neoliotomus*” (McKenna, 1960; p11). However, referral of the incisors was tentative (e.g., cf. *Neoliotomus* sp.) because *Neoliotomus* was not known from strata older than Tiffanian and the presence of a then unnamed anisonchine or conacodontine periptychid from UCMP V5252 (site stratigraphically equivalent to V5870) suggested that this part of the Goler Formation was Puercan or Torrejonian in age (McKenna, 1960; McKenna et al., 1987). The unnamed periptychid, now *Goleroconus alfi*, is considered a relict Tiffanian taxon

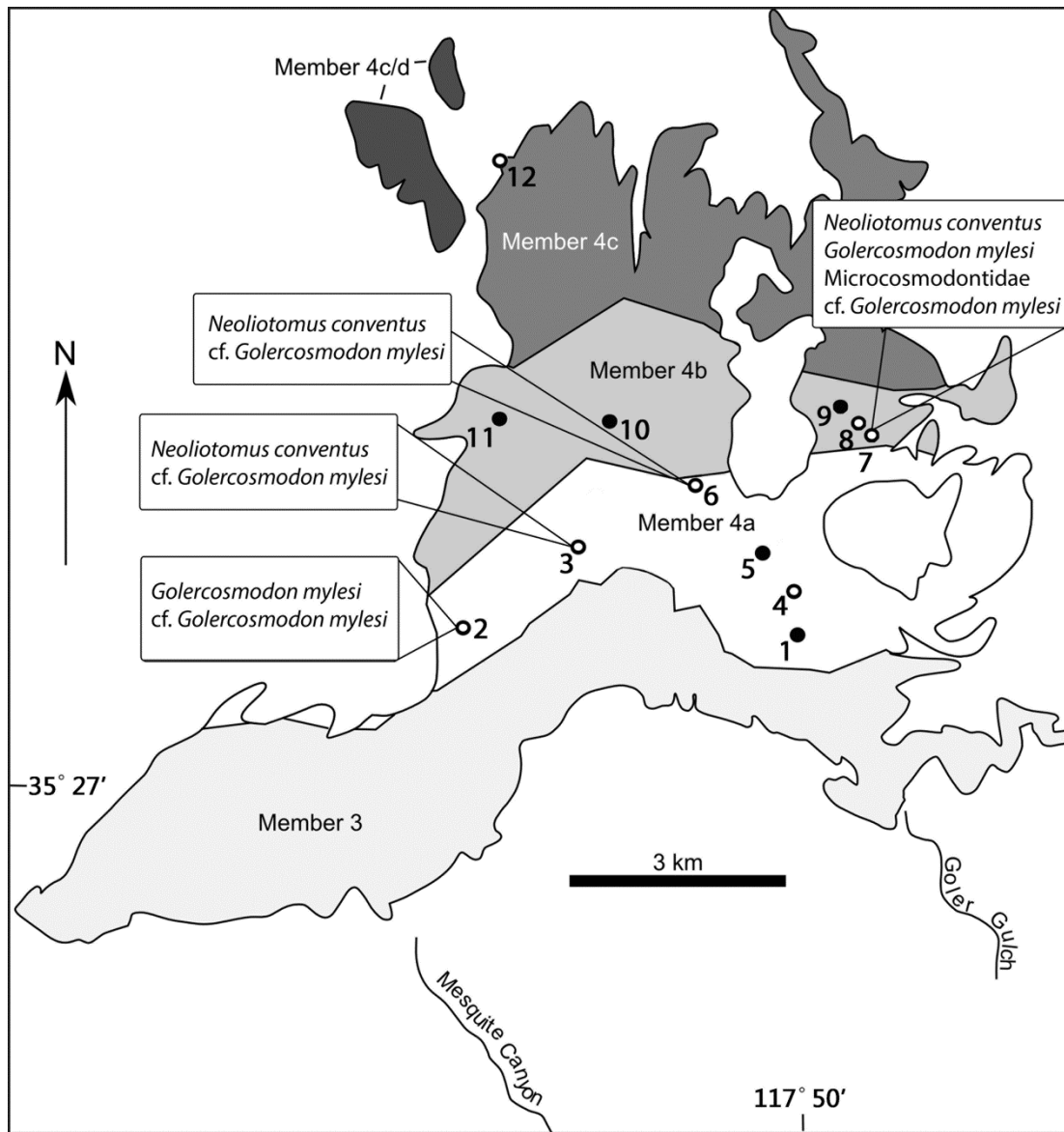


FIGURE 1. Outcrop map of members 3 and 4 of the Goler Formation within the El Paso Mountains (adapted from Cox, 1982; Cox and Diggles, 1986) showing location of sites discussed in text; members 1 and 2 not shown. Numbers refer to a specific site or group of sites within a limited geographic area, with the numerical order reflecting the approximate stratigraphic sequence of RAM localities. Open circles are areas where strata at a specific site underwent paleomagnetic analysis; results presented in Albright et al. (2009). Localities that yielded multituberculates described in the text are in bold and multituberculate taxa recovered from each are shown in box inserts. 1) Red Flat area (V201014, V201122); 2) Grand Canyon area (V200508, **V200510**, V200706, V200802, V200804); 3) Land of Oz (**V200001**); 4) *Phenacodus* Pocket area (V200603, V200612); 5) R-Z Zone area (V200303, V200304, V200702); 6) Laudate Discovery Site area (**V91014**, **V94133**); 7) Edentulous Jaw Site (**V98012**); 8) Primate Gulch (V200202); 9) Lone Tooth (V200704); 10) Butte Tooth (V200613); 11) Honey Pot (V200120); 12) Shark Site (V200307).

that is mostly closely related to Puercan and Torrejonian taxa from the Western Interior (McKenna et al., 2008; Lofgren et al., 2014).

The two UCMP incisors were also referred to *Neoliotomus* cf. *conventus* by R. Sloan (in West, 1976). The broken lower incisor of the holotype of *N. conventus* (PU 13297) is 2.5 mm in width and 6.3 mm

in depth (Krause, 1980; table 8), similar to the size of the Goler incisors (UCMP 55399, width 2.5 mm, depth 6.9 mm; UCMP 49490 width 2.3 mm, depth 6.5 mm). With recovery of the most diagnostic tooth of *N. conventus*, a P4 (RAM 7237) from the Goler Formation, there is little doubt of the affinity of the two UCMP incisors with *N. conventus*.

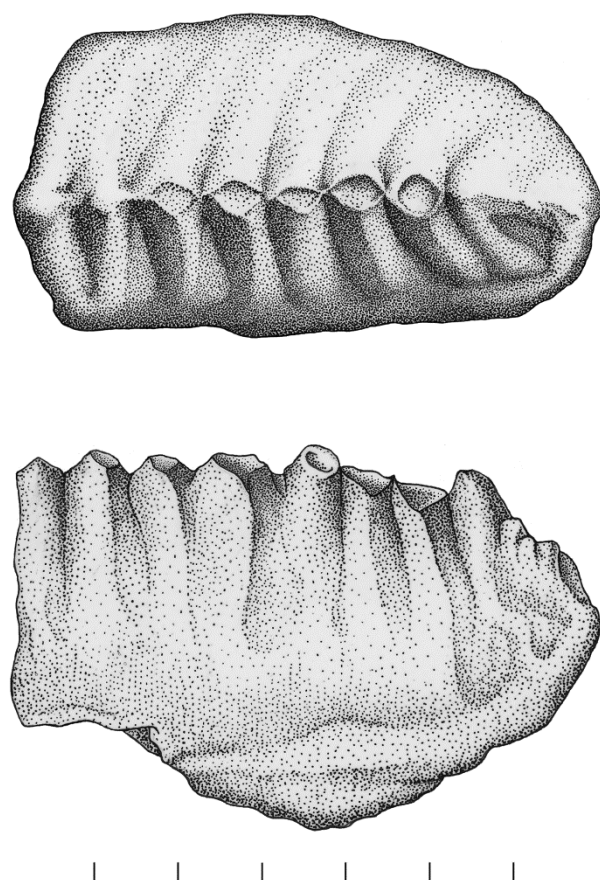


FIGURE 2. Occlusal (top) and lingual views (bottom) of RAM 7237, left P4 fragment of *Neoliotomus conventus*. Scale in mm.

In 2000, M. McKenna found a large, heavily damaged multituberculate p4 (RAM 7204) from RAM locality V200001 (member 4a) that is tentatively referred here to *Neoliotomus conventus* based primarily on size. RAM 7204 is deeply weathered and a large portion of the anterior part of the crown is missing due to breakage (Figure 3). The enamel of RAM 7204 is incomplete as only the posterior part of the crown apex has an enamel cover. A well-developed posterolabial cusp is present and at least seven serrations with ridges are evident on the preserved enamel (Figure 4). If other faintly visible ridges that lack serrations are counted, at least 11 serrations were once present on RAM 7204. This count should be considered a minimum because damage, especially to the anterior part of RAM 7204, removed evidence of additional serrations. The broken p4 of the holotype of *N. conventus* (PU13297) has eleven serrations and is estimated to have once had 14 or 15 (Jepsen, 1930a). A cast of FMNH 26082, a complete p4 identified as *N. conventus* from the Debuque Formation of Colorado (Kihm, 1984), has 14



FIGURE 3. Labial (top) and lingual views (bottom) of RAM 7204, damaged right p4 tentatively identified as *Neoliotomus conventus*. Scale equals 5 mm.

serrations. As preserved, RAM 7204 is 3.1 mm in width and 11.5 mm in length. Restoring the missing posterior and anterior sections of RAM 7204 based on a comparison to FMNH 26082, indicates that RAM 7204 was approximately 13.5 mm in length, if both specimens had the same number of serrations.

When Jepsen (1930a) described the holotype of *Neoliotomus conventus* (PU 13297), he noted that *N. conventus* was about 25% larger than *Neoliotomus* (“*Euscosmodon*”) *ultimus*, a smaller species known from early Eocene strata. The complete right p4 of *N. conventus* from the Dubuque Formation (FMNH 26082) is 13.4 mm in length and the p4 of *N. ultimus* ranges in length from 10.6 mm to 12.6 mm (Krause, 1982; table 9). RAM 7204 is about 13.5 mm in length,

which is within the size range of *N. conventus*, but not that of *N. ultimus*.

*Neoliotomus conventus* is known from late Tiffanian (Ti5a) through Clarkforkian strata in the northern Rocky Mountain states (Krause, 1980; Secord, 2008) and perhaps late Torrejonian (To3) strata in the San Juan Basin of New Mexico (Weil et al., 2012). The Goler Formation assemblage of eutherian mammals and magnetostratigraphic correlations suggest a middle Tiffanian (Ti3–Ti4a) age for members 4a and 4b (Lofgren et al., 2014). Based on a few very large specimens of *N. conventus* from late Tiffanian strata in the Bighorn Basin of Wyoming, there may be a mean decrease in size in *Neoliotomus* from the late Tiffanian through the Clarkforkian, which may justify naming of a new late Tiffanian species of *Neoliotomus* (Krause, 1980; Secord, 2008). The presence of *N. conventus* in the Goler Formation would be important in this regard as Goler specimens appear to be older than those from the Bighorn Basin, but the available sample is too fragmentary to offer any further insight into this issue.

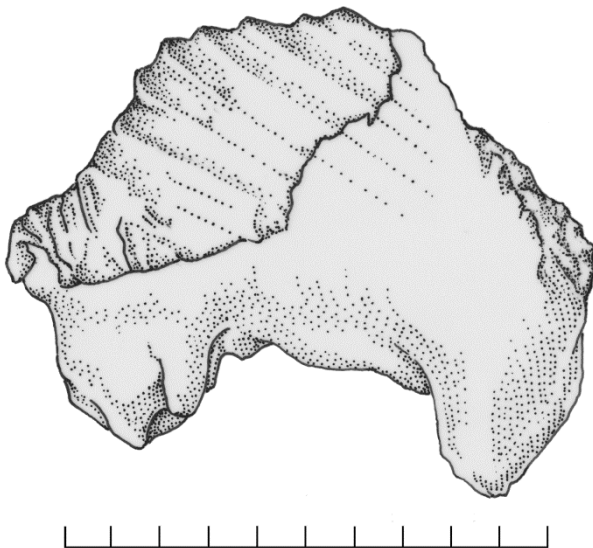


FIGURE 4. Drawing of RAM 7204, damaged right p4 tentatively identified as *Neoliotomus conventus* in labial view, showing details of serration and ridge preservation. Scale bar in mm.

Family Microcosmodontidae Holtzman and Wolberg,  
1977

*Golercosmodon* gen. nov.

**Diagnosis**—as for the holotype and only species.

**Etymology**—*Goler*, in reference to the Goler Formation, *-cosmodon*, by analogy with other microcosmodontids.

*Golercosmodon mylesi* sp. nov.  
(Figure 5A–C, Table 1)

**Holotype**—RAM 6968, left P4 (Figure 5B), from RAM locality V98012, member 4b, Goler Formation, California.

**Referred specimens**—RAM 6965 right P4 (Figure 5A) and RAM 9656 posterior 60% of right P4 from RAM locality V98012, member 4b; RAM 9685 right P4 (Figure 5C) from RAM locality V200510, member 4a.

**Etymology**—Named in honor of Douglas F. Myles, for his guidance and support of the Raymond M. Alf Museum of Paleontology for more than two decades.

**Diagnosis**—Compared to other Tiffanian microcosmodontids, the P4 of *Golercosmodon mylesi* is smaller than those of *Allocosmodon woodi* and *Alopocosmodon hadrus*, larger than those of *Pentacosmodon bowensis*, *Microcosmodon conus* and *Acheronodon vossae*, and has six or seven medial row cusps, more than any other microcosmodontid. The P4 cusp formula of *Golercosmodon mylesi* is most similar to that of *Allocosmodon woodi* and *Acheronodon vossae*, but *Golercosmodon mylesi* differs from *Allocosmodon woodi* in the absence of significant development of an anterolabial bulge and in having a rounded anterior tooth margin and a labial cusp row whose first cusp is positioned posterior to the first medial row cusp. The P4 of *Acheronodon vossae* also differs from *Golercosmodon mylesi* in having a relatively narrower labial cusp row lobe and smaller labial row cusps in relation to the overall size of the crown.

**Description**—Three complete P4s referred to *Golercosmodon mylesi* all display the typical microcosmodontid morphology of having three rows of cusps where the crown is dominated by a medial cusp row that spans the entire length of the tooth and traverses obliquely from the anterolingual edge to the posterolabial margin (Figure 5A–C). In occlusal view, P4s of *G. mylesi* have an elongate rectangular shape with a rounded anterior edge and a posterior edge that is tapered or slightly squared. There is a faint constriction in width present on the lingual margin adjacent to cusp four in the medial cusp row in RAM 6968 (holotype) and RAM 6965 (Figure 5A–B). Wear on all P4s of *G. mylesi* is concentrated on the posterior half of the tooth especially on the occlusal and lingual surfaces of the posterolingual ridge, the occlusal surface of medial row cusps six and seven, and the lingual face of medial row cusp four.

Labial row cusps in *Golercosmodon mylesi* are relatively large compared to the size of the crown and exhibit considerable variation as RAM 6965 has one labial row cusp, RAM 6968 (holotype) has two, and



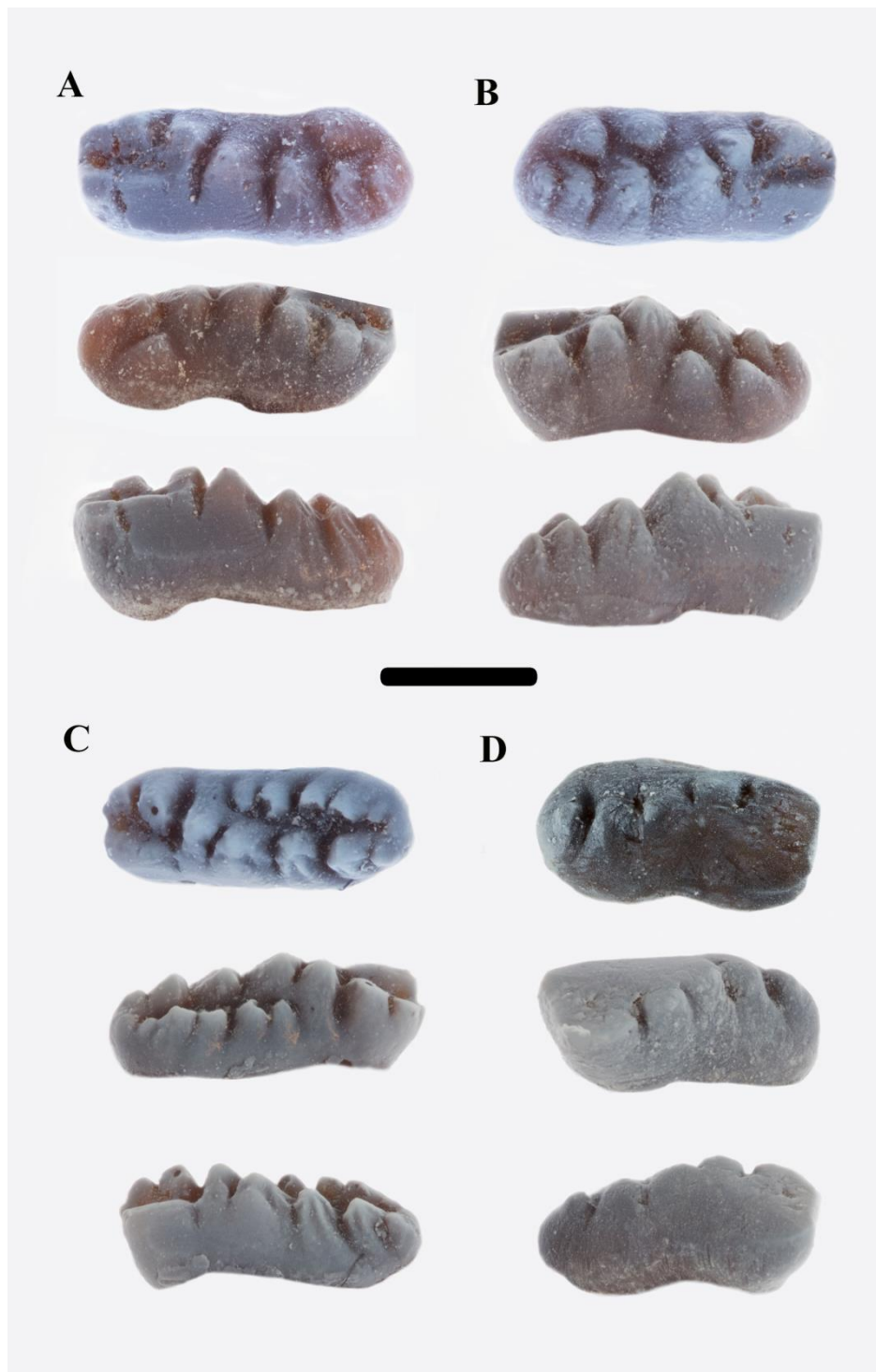


FIGURE 5. Occlusal view of P4s of *Golercosmodon mylesi* (A-C) and the P4 of *Microcosmodontidae* genus and species indeterminate (D). A) RAM 6965, right P4 of *G. mylesi*; B) RAM 6968, left P4 (holotype) of *G. mylesi*; C) RAM 6985, right P4 of *G. mylesi*; D) RAM 9987, left P4 of *Microcosmodontidae* genus and species indeterminate. Scale bar equals 1 mm.

RAM 9685 has four (Figure 5A-C). The single labial row cusp in RAM 6965 is positioned opposite a position between medial row cusps two and three, and the anterior labial row cusp of RAM 6968 (holotype) is also positioned opposite a position between medial row cusps two and three (the posterior labial row cusp is positioned opposite a position between medial row cusps three and four in the holotype).

With four labial row cusps, RAM 9685 appears to be an extreme morphological variant of *Golerocosmodon mylesi*. Labial row cusps one through three are subequal in size, cusp four is slightly smaller, and an additional minute cuspule is present anterior to cusp one (Figure 5C). The bases of labial row cusps one and two are closely appressed, in contrast to labial row cusps three and four which are well separated. The transverse relationship of cusps of the medial and labial cusp row for RAM 9685 are as follows: labial row cusp one opposite medial row cusp two, labial cusp two opposite a position just anterior to apex of medial cusp three, labial cusp three opposite a position between medial cusps three and four, and labial cusp four opposite medial cusp four (Figure 5C). RAM 9685 lacks any trace of a mid-length constriction, a condition probably related to its unusually well-developed labial cusp row.

Medial row cusps one through four in *Golerocosmodon mylesi* are usually pyramidal, with enamel crenulations commonly present on the anterior slope of each cusp. In RAM 6965 and RAM 9685, where the medial row has seven cusps, cusps one and two are closely appressed as are cusps six and seven. For both, their fourth cusp is the largest and one the smallest, with cusps four and five tallest and subequal in height. RAM 6968 has six medial row cusps, with cusps one and two closely appressed, the fourth cusp the largest and first cusp the smallest, and cusps four and five tallest and subequal in height. Medial row cusps of RAM 6985 are not as pyramidal in shape as medial row cusps of RAM 6968 and RAM 6965.

The lingual row of the P4 of *Golerocosmodon mylesi* is short, oriented anteroposteriorly, and ridge-like without distinct cusp development, even though the lingual cusp row of RAM 9685 appears to have minimal wear. However, there is small valley in RAM 6965 that bisects the lingual ridge, suggesting two lingual cusps were once present before wear obscured them. Thus, the lingual cusp row of *G. mylesi* is represented by a ridge (with perhaps two cusps) whose length approximates that of the length of medial row cusps six and seven in RAM 9685 and RAM 6965.

**Discussion**—Isolated teeth referred to *Golerocosmodon mylesi* from Tiffanian strata of the Goler Formation, represent the first definitive records of microcosmodontids from the west coast of North

America other than the tentatively referred incisor (UCMP 124426) to cf. *Microcosmodon* reported by McKenna et al. (1987). Initial descriptions of Microcosmodontidae were from late Paleocene strata in the Bighorn Basin of Wyoming (Jepsen, 1930b, 1940; *Microcosmodon conus* and *Pentacosmodon pronus*). Later, *Acheronodon garbani* (Archibald, 1982) and additional specimens of *Microcosmodon* were reported from other Rocky Mountain States and southern Canada (*“Microcosmodon” woodi*, Holtzman and Wolberg, 1977; *M. arcuatus*, Johnston and Fox, 1984; *M. rosei*, Krause, 1980; *M. harleyi*, Weil, 1998). More recently, Fox (2005) described a multitude of microcosmodontid specimens, including dentaries and partial skulls, from a series of localities in the Paskapoo Formation of Alberta which greatly increased knowledge of the anatomy and taxonomy of the Microcosmodontidae. Tiffanian specimens described by Fox (2005) included the new species *Acheronodon vossae* and *Pentacosmodon bowensis* and additional specimens of *Pentacosmodon pronus* and *Microcosmodon conus*, as well as reassignment of *“Microcosmodon” woodi* to the new genus, *Allocosmodon*. As noted by Weil and Krause (2008), Fox (2005) removed *Microcosmodon arcuatus* and *M. harleyi* from *Microcosmodon* but did not refer them to any new or previously described taxon. Most recently, Scott et al. (2012) described *Alopocosmodon hadrus*, a middle Torrejonian microcosmodontid from the Porcupine Hills Formation of Alberta.

The p4 is the most diagnostic tooth of microcosmodontids (Fox, 2005) and the lack of one for *Golerocosmodon mylesi* makes its generic assignment somewhat tenuous. However, the three complete P4's (RAM 6968, RAM 6965, RAM 9685) referred to *G. mylesi* from the Goler Formation have a suite of features that differ significantly from P4s of any known microcosmodontid. The P4 of *G. mylesi* has six to seven medial row cusps, a number that far exceeds P4s of *Pentacosmodon bowensis* (three or four medial row cusps; Fox, 2005), *Microcosmodon conus* (four or five medial row cusps, Table 1), and *Alopocosmodon hadrus* (four medial row cusps; Scott et al., 2012), and a number that is slightly higher than P4s of *Allocosmodon woodi* (four to six medial row cusps, Table 1) and *Acheronodon vossae* (five to six medial row cusps, Table 1). The P4s of *Allocosmodon woodi* and *Acheronodon vossae* also differ from those of *Golerocosmodon mylesi* in the development of the labial cusp row. In P4s of *Allocosmodon woodi* from the DW-2 locality in Alberta, the labial row is convex and curves around the anterior margin of the tooth so that the first labial row cusp is positioned anterior to the first medial row cusp (Fox, 2005; plate 7, figs. 13, 16, 19). Associated with this feature are a well-developed

TABLE 1. Measurements of P4s of *Microcosmodon conus* and *Acheronodon vossae* from Alberta, *Allocosmodon woodi* from North Dakota and Alberta, and *Golercosmodon mylesi* and an unidentified microcosmodont from California. Measurements of UMVP 5938, SMM P77.8.1, and SMM P77.8.2 from Holtzman and Wolberg (1977; table 1). Measurements of UALVP specimens from Fox (2005).

Specimen	Length	Width	Cusp Formula
<i>Microcosmodon conus</i>			
UALVP 42791	1.8	0.8	2:4+:?
UALVP 42816	1.7	0.7	2:4+:?
UALVP 42821	1.7	0.8	2:4+:1?
UALVP 40687	1.7	0.6	3:4+:?
UALVP 42769	1.7	0.8	2:5:1?
UALVP 42770	1.8	0.7	3:5:1
UALVP 42773	1.7	0.8	3:5:3
<i>Acheronodon vossae</i>			
UALVP 24551	1.7	0.7	3:5:1
UALVP 24554	1.7	0.6	3:5:?
UALVP 24555	1.6	0.7	3:6:?
UALVP 24558	1.6	0.7	2:5:?
UALVP 42925	1.7	0.7	2:5:2
UALVP 42926	1.6	0.7	2:5:?
<i>Allocosmodon woodi</i>			
UMVP 5938	2.2	0.9	2:4
SMM P77.8.1	2.3	1.0	3:5
SMM P77.8.2	2.1	0.9	3:4
UALVP 40478	2.3	1.1	3:5:1
UALVP 40493	2.4	0.9	3:6:3
UALVP 40498	2.3	1.0	3:4?:1
<i>Golercosmodon mylesi</i>			
RAM 9685	2.0	0.9	4:7:ridge
RAM 6965	2.1	0.9	1:7:2?
RAM 9656	---	0.9	?:?:ridge
RAM 6968	2.1	0.9	2:6:ridge
Microcosmodontidae gen. & sp. indet.			
RAM 9987	1.8	0.9	0:5?:?



anterolabial bulge and a blunt anterior tooth margin. In *Golercosmodon mylesi* the first labial row cusp is positioned posterior to the first medial row cusp as the labial cusp row does not curve around the anterior margin of the tooth. Also, a distinct anterolabial bulge is not developed and the anterior margin of the tooth is rounded in *G. mylesi* (Figure 5A-C).

The P4 of *Acheronodon vossae* has a rounded anterior tooth margin like the P4 of *Golercosmodon mylesi*, but differs from *G. mylesi* in having a labial cusp row that also curves around the anterior margin of the tooth so that the first labial row cusp is positioned anterior to the first medial row cusp (Fox, 2005; plate 9, figs. 17, 20). The P4 of *Acheronodon vossae* is described as having one to four labial row cusps (like *Golercosmodon mylesi*), but the list of referred specimens of *Acheronodon vossae* lacks any reference to a P4 having more than three labial row cusps (Fox, 2005). Finally, *A. vossae* differs from *Golercosmodon mylesi* in having a narrow anterolabial lobe with smaller labial row cusps in relation to the overall size of the crown, a character that also differentiates *Allokosmodon woodi* from *Acheronodon vossae* (Fox, 2005).

Microcosmodontidae genus and species indeterminate (Figure 5D)

**Referred Specimen**—RAM 9987, left P4 from RAM locality V98012, member 4b of the Goler Formation.

**Description-Discussion**—RAM 9987 is a heavily worn P4 (Figure 5D). Four cusps are evident on the posterolingual part of the tooth, so there appears to have been at least five medial row cusps. Heavy wear has merged the medial and lingual cusp rows of RAM 9987 and the tooth appears to lack any development of a labial cusp row. In occlusal view, RAM 9987 has a more squared outline than the rectangular shaped P4s of *Golercosmodon mylesi* (Figure 5A-C, D) as it is distinctly shorter in length. Although RAM 9987 is too worn to be confidently identified to taxon, its small size (Table 1) and squared shape in occlusal view indicate that there are at least two microcosmodontids in the Goler Formation.

cf. *Golercosmodon mylesi*  
(Figure 6A-H; Table 2)

**Referred Specimens**—RAM 7232 incomplete right M1, RAM 6969 right M1, RAM 6970 right M2, RAM 6971 right M2, RAM 6434 left M2, RAM 9999 right M2, RAM 9988 right M2, RAM 7230 M2, RAM 6483 incomplete right M2, RAM 6731 incomplete right m1, RAM 6975 right m1, RAM 7235 incomplete

m1, RAM 6463 incomplete m1, RAM 9993 right m1, RAM 9971 right m1, RAM 9995 left m2, RAM 6967 right m2, RAM 9990 left m2, RAM 9974 right m2, RAM 9975 incomplete left m2, RAM 9972 left m2, from RAM locality V98012, member 4b; RAM 6980 incomplete right m1, RAM 9676 right m2, from RAM locality V200510, member 4a; RAM 6447 left m1, RAM 6422 right m1, from RAM locality V94014, member 4a; UCMP 124426 lower incisor from UCMP locality V5252 (equals RAM locality V94014); RAM 9722 left m2 from RAM locality V200001 member 4a.

**Discussion**—Many isolated microcosmodontid molars were recovered from the Goler Formation that cannot be confidently referred to a specific genus and two specimens for each tooth site are illustrated (Figure 6A-H) to demonstrate the diversity of the sample. To identify the taxon of isolated microcosmodontid molars usually requires comparative material where molars are associated with a p4 or P4, like maxillae and dentaries of Tiffanian microcosmodontids described by Fox (2005), a prospect unlikely for the sparsely fossiliferous Goler Formation. However, most of these isolated teeth probably represent *Golercosmodon mylesi* based on relative abundance, as four of the five (80%) microcosmodontid P4s from the Goler Formation were referred to *G. mylesi*. The size and cusp formula of these isolated teeth are listed in Table 2. We tentatively assign these specimens to *G. mylesi* with the caveat that subsequent referral to other taxa is possible.

A multituberculate incisor from member 4a (UCMP 124426) was described by McKenna et al. (1987) as closely comparable to *Microcosmodon*. We include this lower incisor with other isolated teeth questionably referred to *Golercosmodon mylesi* as it has no unique features that align it with *Microcosmodon*.

## DISCUSSION

Multituberculates described here from member 4a and the lower part of member 4b of the Goler Formation increase the known taxonomic diversity of the Microcosmodontidae and confirm the previously proposed geographic range extension of *Neoliotomus* and microcosmodontids to the west coast of North America (McKenna, 1960; McKenna et al., 1987) during the late Paleocene. Mammalian assemblages from sites located throughout this 500 m stratigraphic interval of member 4 were collectively referred to as the Goler Assemblage because these strata could not be subdivided into discrete biostratigraphic units (Lofgren et al., 2014). *Golercosmodon mylesi*, *Neoliotomus conventus*, and cf. *Golercosmodon mylesi* occur in both member 4a and the lower part of member 4b, and

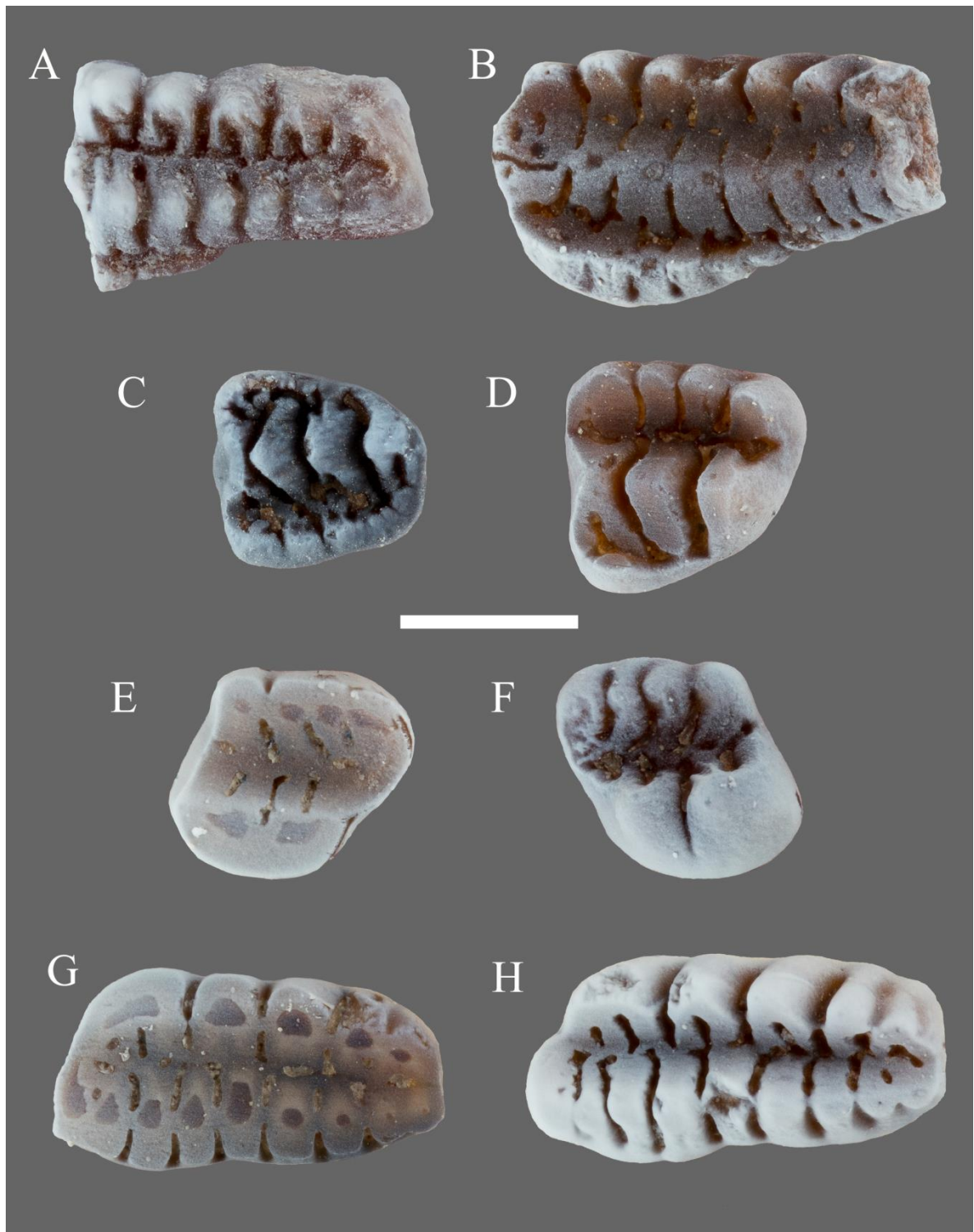


FIGURE 6. Occlusal view of M1s, M2s, m2s, and m1s that may represent *Golercosmodon mylesi*. A) RAM 7232, incomplete right M1; B) RAM 6969, right M1; C) RAM 6434, left M2; D) RAM 9999, right M2; E) RAM 9974, right m2; F) RAM 9972, left m2; G) RAM 9971, right m1; H) RAM 9993, right m1. Scale bar equals 1 mm.

TABLE 2. Measurements of molars of cf. *Golercosmodon mylesi* from the Goler Formation of California. \* Minimum, broken tooth.

Specimen	Tooth Site	Length	Width	Cusp Formula
RAM 7232	M1	1.9*	1.2*	7:8:4
RAM 6969	M1	2.8	1.5	7:8:5
RAM 7230	M2	1.4	---	1:3:?
RAM 9999	M2	1.5	1.3	1:3:5
RAM 6971	M2	1.5	1.3	1:3:4
RAM 9988	M2	1.3	1.4	1:3:4
RAM 6483	M2	1.6	1.3*	1:3:4
RAM 6970	M2	1.3	1.3	1:3:4
RAM 6434	M2	1.8	1.7	1:4:4
RAM 6422	m1	2.4	1.2	7?:4
RAM 6975	m1	2.5	1.3	8?:5?
RAM 6447	m1	2.2	1.1	9:5
RAM 7235	m1	1.4*	1.1	----
RAM 6731	m1	1.9*	1.1	6:4
RAM 9993	m1	2.4	1.2	9:5
RAM 9971	m1	2.3	1.2	7:5
RAM 9680	m1	1.7*	1.1	----
RAM 9676	m2	1.7	1.6	5:2
RAM 6967	m2	1.6	1.5	5:2
RAM 9974	m2	1.3	1.2	4:2
RAM 9995	m2	1.4*	1.4	4:2
RAM 9975	m2	1.4	1.5	4:2
RAM 9972	m2	1.3	1.4	4:2
RAM 9722	m2	1.6	1.4	4:2
RAM 9990	m2	1.5	1.3	4:2

Microcosmodontidae genus and species indeterminate is only known from one specimen from member 4b (Figure 1). Thus, no additional support is provided by multituberculates with regard to biostratigraphic subdivision of the stratigraphic interval comprised of member 4a and the lower part of member 4b of the Goler Formation (Table 3).

Comparison of the eutherian part of the Goler Assemblage to Tiffanian biozone ranges of mammalian taxa from sites elsewhere in the Western Interior, indicated a Ti3–Ti4a age as 14 of 15 Goler eutherian taxa had ranges that overlap in the Ti3–Ti4a biozones (Lofgren et al., 2014; fig. 14); the one exception is *Paromomys*, whose youngest known record is Ti1 (Lofgren et al., 2004). Also, all but one magnetic polarity sample from member 4a and the lower part of member 4b were reversed (Albright et al., 2009) and

they were interpreted to represent 26r, a magnetostratigraphic correlation that is compatible with the proposed Ti3–Ti4a age of the Goler Assemblage (Lofgren et al., 2014); if C25r or C27r were interpreted as correlative to the reversed Goler samples, there would be many significant taxon range extensions (Figure 7), a much less likely scenario.

Of the two definitively identified multituberculate taxa described here (*Golercosmodon mylesi* and *Neoliotomus conventus*), *N. conventus* is important to biochronologic correlation of the Goler Assemblage as it is known from late Tiffanian (Ti5a) through Clarkforkian strata in the Rocky Mountain States (Krause, 1980; Secord, 2008). However, *Neoliotomus* has been listed as occurring in late Torrejonian strata in New Mexico (Weil et al., 2012), but description of specimens supporting this assertion have yet to appear.

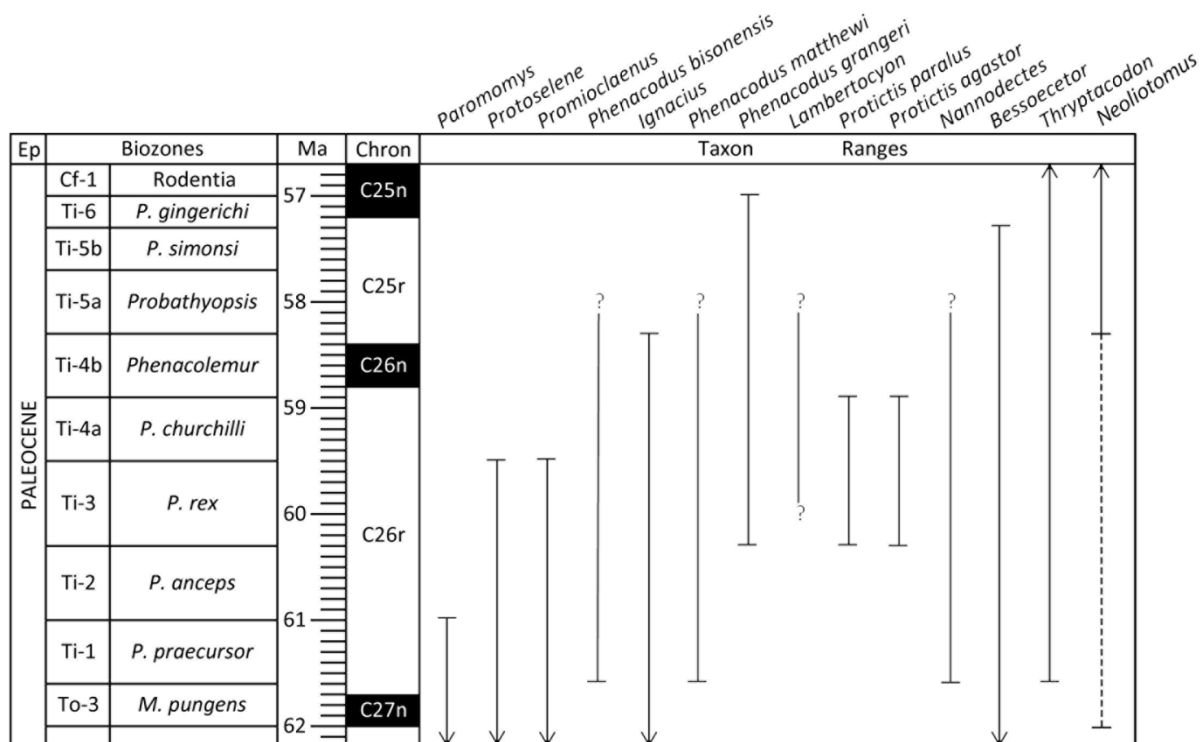


FIGURE 7. Presently known temporal ranges of selected eutherian mammals and the multituberculate *Neoliotomus* known from the Goler Assemblage based on occurrences from the Western Interior of North America. Biochronology and geochronology adapted from Albright et al. (2009; fig 4), but based on Secord et al. (2006; fig. 3).

Thus, the presence of *Neoliotomus conventus* in the Goler Assemblage could indicate a Ti5 or younger age, but the majority of temporal ranges for the Goler Assemblage suggest a Ti3–Ti4 age, assuming that the lineage zone subdivision of the Tiffanian developed mainly from faunal assemblages of the Rocky Mountains (Gingerich, 1976; Secord et al., 2006; Secord, 2008) can be extended to California. If so, the Goler Formation may yield the oldest known record of *Neoliotomus* and the youngest known record of *Paromomys*.

The Goler Assemblage exhibits significant endemism as about 40 percent of eutherian and metatherian taxa presently known from the Goler Formation have not been found in Tiffanian faunas from the Western Interior and only about 20% of Goler Assemblage eutherians could be confidently referred to previously named species (Lofgren et al., 2014). Of the two definitively identified multituberculate taxa from the Goler Formation, *Neoliotomus conventus* is known from the Western Interior, whereas *Golerocosmodon mylesi* represents a new endemic taxon. Thus, although based on admittedly sparse data, the degree of endemism exhibited by Goler multituberculates

approximates that of the eutherian and metatherian components of the Goler Assemblage. Significant distances and one or more paleodrainages separated the Goler depositional basin from Western Interior basins, potentially limiting dispersal of mammals between the west coast and the continental interior of North America in the late Paleocene. This appears to have resulted in the development of a discrete Goler faunal province (Lofgren et al., 2014) and the endemic multituberculate *G. mylesi* provides further support for this assertion.

## SUMMARY

Early collecting efforts in the Goler Formation yielded multituberculate incisors that were tentatively identified as cf. *Neoliotomus* and cf. *Microcosmodon*. Recent collecting efforts resulted in the discovery of three multituberculate taxa, including a new genus and species of microcosmodontid. The Goler sample of *Neoliotomus* now includes a P4 that exhibits the diagnostic morphology of *Neoliotomus conventus* and confirms the presence of this rare taxon in California. *Golerocosmodon mylesi* is a new genus and species of

TABLE 3. Eutherians, metatherians, and multituberculates (\*) from members 4a and 4b of the Goler Formation. In parentheses are the number of specimens per taxon; taxa without numbers are one single specimen occurrences. Eutherians based on Lofgren et. al. (2014) and metatherians (*Peradectes* sp. and *Golerdelphys stocki*) based on Williamson and Lofgren (2014). Modified from Lofgren et al. (2014:table 13).

Member 4a	Member 4b
<i>Peradectes</i> sp.	<i>Peradectes</i> sp. (2)
<i>Nannodectes lynasi</i> (6)	<i>Nannodectes lynasi</i> (15)
<i>Phenacodus</i> cf. <i>P. bisonensis</i> (20)	<i>Phenacodus</i> cf. <i>P. bisonensis</i> (3)
<i>Goleroconus alfi</i> (4)	<i>Goleroconus alfi</i>
* <i>Neoliotomus conventus</i> (3)	* <i>Neoliotomus conventus</i>
* <i>Golercosmodon mylesi</i>	* <i>Golercosmodon mylesi</i> (3)
cf. * <i>Golercosmodon mylesi</i> (6)	cf. * <i>Golercosmodon mylesi</i> (21)
	* <i>Microcosmodontidae</i>
	<i>Golerdelphys stocki</i> (5)
	<i>Ignacius frugivorus</i>
<i>Taeniodonta</i>	
<i>Bessoecetor septentrionalis</i>	
<i>Protictis paralus</i>	
<i>Protictis</i> cf. <i>P. agastor</i>	
<i>Paromomys depressidens</i>	
<i>Thryptacodon</i> sp.	
<i>Mimotricentes tedfordi</i> (5)	
<i>Lambertocyon</i> cf. <i>L. gingerichi</i> (2)	
<i>Protoselene ashtoni</i>	
<i>Promioclanius walshi</i> (3)	
<i>Phenacodus</i> cf. <i>P. matthewi</i>	
<i>Phenacodus</i> cf. <i>P. grangeri</i>	
<i>Dissacus</i> sp.	

microcosmodontid based on P4s which differ from those of all other microcosmodontids in the development of the labial cusp row and in having a higher number of medial row cusps. Tentative referral of isolated microcosmodontid molars from the Goler Formation to *G. mylesi* is based on the high relative abundance of P4s (80%) of *G. mylesi*. An additional microcosmodontid P4 was too worn for confident identification, but it does not resemble *G. mylesi* in size or general occlusal outline, and thus confirms the presence of a second microcosmodontid species in the Goler Formation.

The Goler Formation occurrence of *Neoliotomus conventus* indicates it may have been present in California in the mid-Tiffanian, predating its late Tiffanian appearance in the Western Interior. The presence of the endemic microcosmodont,

*Golerosmodon mylesi*, increases the diversity of microcosmodontids and provides additional support that there was a discrete Goler faunal province on the west coast of North America during the late Paleocene.

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