CLIMATE AND ECOLOGICAL CHANGE IN OLIGO-MIOCENE MAMMALS

by

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A DISSERTATION

Presented to the Department of Geological Sciences
and the Graduate School of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

December 2011

DISSERTATION APPROVAL PAGE

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Title: Climate and Ecological Change in Oligo-Miocene Mammals

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DISSERTATION ABSTRACT

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Whether or not a causal relationship exists between climate and mammal body size is one of the longest-standing and most intractable questions in ecology. The classic model of body size evolution (Bergmann's Rule) holds that body size is driven by temperature, but more recent hypotheses have suggested that other climatic variables or biotic interactions may play a more important role. The use of paleoecological data to address this question allows variables that are tightly correlated in modern ecosystems to be teased apart and allows body size patterns to be observed through time, adding an extra dimension to analyses. This dissertation details the findings of two paleoecological tests of Bergmann's Rule in the Oligo-Miocene (30-5 Ma), one tracking body size and climate through time in the northwestern United States and another tracking geographic body size trends through time along the west coast of North America. In both cases, body size was analyzed in three representative families of mammals: equids, canids, and sciurids. Such large-scale analyses are dependent on fossils that can be placed in a reliable taxonomic, geologic, and temporal context, and this dissertation also focuses on a reevaluation of the canid fauna of Oregon's Juntura Formation that places a critically important Late Miocene carnivore fauna in just such a context. Two genera of canids – *Epicyon* and *Carpocyon* – are described from the fauna for the first time, with important implications for regional biostratigraphy. The body size analyses show no consistent relationship between body size and any climatic variable. Further, body size patterns vary widely between taxa at several levels, suggesting that one universal driver of body size evolution does not exist. Not only is there no evidence for Bergmann's Rule in Oligo-Miocene mammals, but comparative analyses of geographic body size patterns in the modern genera *Odocoileus*, *Canis*, and *Spermophilus* fail to show the latitudinal gradients upon which Bergmann's Rule is predicated. The apparent existence of such trends in some taxa may be the result of anthropogenic extirpation at low latitudes, further underscoring the importance of including paleontological data when formulating models predicting the response of biotic variables to environmental change.

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Orcutt, J.D., and S.S.B. Hopkins. In review. Oligo-Miocene climate change and mammal body size evolution in the northwest United States. Palaeogeography, Palaeoclimatology, Palaeoecology.

Orcutt, J.D., and S.S.B. Hopkins. 2011. The canid fauna of the Juntura Formation (Late Clarendonian, Oregon). Journal of Vertebrate Paleontology 31:700-706.

ACKNOWLEDGMENTS

This project was specimen-based and would have been impossible without the curators and staff of the fossil collections I visited and recent collections whose data I included. In particular, I would like to thank Judy Galkin (American Museum of Natural History), Ismael Ferrusquía Villafranca, Maria Perrilliat Montoya, Violeta Romero Mayén (Instituto de Geología, Universidad Nacional Autónoma de México), Mary Thompson (Idaho Museum of Natural History, Idaho State University), Josh Samuels, Chris Schierup (John Day Fossil Beds National Monument), Sam McLeod, Vanessa Rhue, Gary Takeuchi, Jack Tseng (Natural History Museum of Los Angeles County), Chris Conroy (Museum of Vertebrate Zoology, University of California), Andy Farke (Raymond Alf Museum), Eric Scott (San Bernardino County Museum), George Bromm, Richard Hilton (Sierra College Natural History Museum), Kesler Randall (San Diego Natural History Museum), Sally Shelton (South Dakota School of Mines and Technology), Pat Holroyd, Susumu Tomiya (University of California Museum of Paleontology), Ron Eng, Chris Sidor, Courtney Richards, and Jeff Bradley (Burke Museum, University of Washington).

This work would have also been impossible without input from other paleontologists and geologists. Jim Martin (South Dakota School of Mines and Technology) provided invaluable insight on Clarendonian canids from the Northwest, while Matt Kohn (Boise State University) and Jeff Myers (Western Oregon University) provided feedback on my use of isotopic and paleobotanical climate proxies. I am also indebted to the support and criticism of my committee members throughout the dissertation process. I would especially like to thank my advisor, Sam Hopkins, for her oversight, but Greg Retallack, Becky Dorsey, and Steve Frost also provided suggestions and advice without which I could not have finished this project (thanks are also due to Qusheng Jin, who was a member of my comprehensive examination committee and raised several questions that I had not previously considered). I would like to acknowledge the other members of the Hopkins Lab at the University of Oregon, particularly Edward Davis for his discussions of analytical techniques, Ted Fremd for suggesting Oligo-Miocene paleoecology as a potential dissertation project in the first place, and my fellow graduate students, Jonathan Calede, Win McLaughlin, Nick Famoso, and Kristen MacKenzie for their support, advice, and friendship. Finally, I owe the office staff of the UO Department of Geological Sciences a huge debt of gratitude: Dave Stempel for making sure I got paid, Vicki Arbeiter for making sure I had a job, and Shari Douglas for helping tie up all the loose ends that I left behind me.

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CHAPTER I

INTRODUCTION

Paleontology is a unique area of study: it is fundamentally a geologic science, focusing as it does on fossils preserved in (and often as) rocks, but it also provided crucial evidence for Darwin's (1859) Theory of Evolution by Natural Selection and has informed biological science ever since. Perhaps nowhere is the interdisciplinary nature of paleontology more visible than in the field of paleoecology, the study of how fossil organisms interacted with their environments and how those interactions changed through time. Paleoecology has historically played only a small role in the development of ecological theory, in part because areas with extensive fossil and detailed paleoenvironmental records do not overlap. However, an increased interest in both paleontology and paleoclimatology has begun to make robust paleoecological studies possible. This is especially true in Oregon, where one of the world's most fossiliferous sequences of Oligo-Miocene rocks can be compared directly to a detailed paleoenvironmental record based on the region's paleosols and fossil floras. This dissertation reports the findings of three different – but interrelated – projects that examine paleoecological trends in Oregon and along the West Coast between 30 and 5 million years ago.

Good paleoecological work can only be conducted given a well-established taxonomic and climatological framework, and this first chapter focuses on the former. Canids are the most common large carnivores in most Oligo-Miocene ecosystems, and as such any attempt to understand community dynamics must include an understanding of the canid fauna. Chapter 1 details the canids of the Juntura Formation in Southeast Oregon, a fossil community that has been and continues to be the subject of paleoecological research with local to continental implications (Calede *et al*. 2011, Shotwell 1961, Shotwell 1963). The Juntura canid fauna is much more diverse than previously thought, including two species of the giant borophagine dog *Epicyon* as well as the smaller borophagine *Carpocyon* and an unidentified species of canine. The presence of these taxa has implications for the age of other faunas in the Northwest where these taxa occur, particularly those of the Chenoweth and Ellensburg Formations of the Columbia Plateau, which may inform future paleoecological studies of the region in the Late Miocene.

The second two chapters focus on large-scale trends in body size evolution in canids, as well as in equids and sciurids. Determining which environmental factor or factors drive body size evolution has been one of ecology's most famously intractable debates since it was first addressed by Bergmann (1847). Paleontology can inform this debate in two ways, both of which have been employed here. First, paleontologists can trace body size trends within taxa and determine whether or not those trends track any environmental variables. Second, the fossil record can be used to reconstruct geographic and climatic trends in body size and determine if they exist in some intervals and not others, if they differ significantly from the same trends in modern animals, and if their magnitude varies through time. Both types of test were run as part of this research project, and in neither case was Bergmann's Rule supported over the course of the Oligo-Miocene. This runs counter to received wisdom on body size evolution, but may, in fact, not contradict modern data to any great extent. In either case, the lack of support for latitudinal and climatic gradients in three very distinct groups of mammals over a large interval of the Cenozoic has important implications for models of biotic responses to current and future environmental change.

CHAPTER II

THE CANID FAUNA OF THE JUNTURA FORMATION (LATE CLARENDONIAN, OREGON)

Introduction

The Clarendonian Land Mammal Age (Late Miocene, 12.5–9 Ma; Tedford *et al*. 2004) is an important interval in the evolution of canids. It marks the appearance or the peak abundance of several of the largest taxa of borophagines, including species of *Aelurodon*, *Epicyon*, and *Borophagus* (Wang *et al.* 1999); in fact, it was during the Clarendonian that the largest known species of canid, *E. haydeni*, first appeared. At the same time, the smaller canines were also undergoing a significant radiation, as the earliest members of the two tribes of crown-group canids (Vulpini and Canini) both first appear during this interval (Tedford *et al*. 2009). Clarendonian canids are well known from faunas from the Great Plains and, to a lesser extent, from the southwest United States. However, faunas from other regions in North America generally remain poorly understood.

The Juntura Formation of southeast Oregon preserves the most complete Clarendonian canid fauna from the northwest United States (the Columbia Plateau faunal province of Tedford *et al*. 2004). A preliminary overview of the Juntura fauna including descriptions of some canid material was given by Russell (1956) and Shotwell & Russell (1963). However, many specimens were not included in these papers, and many specimens that were included were assigned to incorrect or currently invalid taxa.

Further, ongoing fieldwork in the Juntura Basin has yielded new canid material, and as such a revised overview of the regional canid fauna is in order.

Methods

All specimens included in this study are from the University of Oregon Museum of Natural and Cultural History Condon Fossil Collection (UOMNH), the primary repository for material from the Juntura Formation. Most of this material was collected by J. Arnold Shotwell and his field crew in the 1950s and 1960s. However, the University of Oregon has recently reestablished a field program in the Juntura Basin that has augmented the collections from that region; one canid specimen (F-42501) has been recovered to date and is included below.

The taxonomic framework for this study is based upon the phylogenies for borophagines presented by Wang *et al*. (1999) and for canines by Tedford *et al*. (2009). These same monographs provide the basis for most of the morphological and size comparisons made below. Munthe's (1989) monograph on borophagine skeletons was used to evaluate postcranial material, though this source generally does not distinguish between which features are characteristic of borophagines and which are actually diagnostic. Where possible, positively identified material from the University of Oregon collections was used for comparative purposes as well.

Geologic Setting

The Juntura Formation outcrops in the basin and around the town of the same name in southeastern Oregon (Figure 1). The Buck Mountain Basalts from the lower part of the formation have been dated to 12.5 Ma (Late Barstovian-Early Clarendonian; Camp *et al*. 2003), and the formation is overlain unconformably by the 9.5 Ma Devine Canyon Ashflow Tuff (Late Clarendonian; Hooper *et al*. 2002). The fossiliferous units of the Juntura Formation (the Juntura fauna of Russell 1956, equivalent to the Black Butte local fauna of Shotwell 1963) are from its uppermost part and are composed primarily of light-colored volcaniclastic sediments (Bowen *et al*. 1963). Based on taxonomic composition, Shotwell & Russell (1963) assigned the fauna to the late Clarendonian (10–9 Ma; Tedford *et al.* 2004).

Specimens included in this study were recovered from seven localities in two distinct outcrops of the Juntura Formation northwest of the town of Juntura: Kingsbury Gulch to the north of US Highway 20 and Black Butte to the south. The Kingsbury Gulch localities (UO 2332 and UO 2333) are both situated on the northeast side of the gulch and are associated with one another: UO2332 is Quarry 2 of Shotwell (1963) and UO2333 comprises float recovered from the area surrounding the quarry. The Black Butte localities UO2335, UO2343, UO2344, and UO2348 are all composed of material collected *in situ*. All of the sites mentioned above are described by Russell (1956), Shotwell (1963), and Shotwell & Russell (1963) and their approximate locations are shown in Figure 1. One canid specimen (UOMNH F42501) has been recovered from a locality that has not been previously described. This locality, UO2597, is located on the western edge of Black Butte (N43°45.3’, W118°08.9’; WGS 84). It comprises float found above a roughly one-meter thick ash layer below the quarry UO2339, from which the specimens likely weathered.

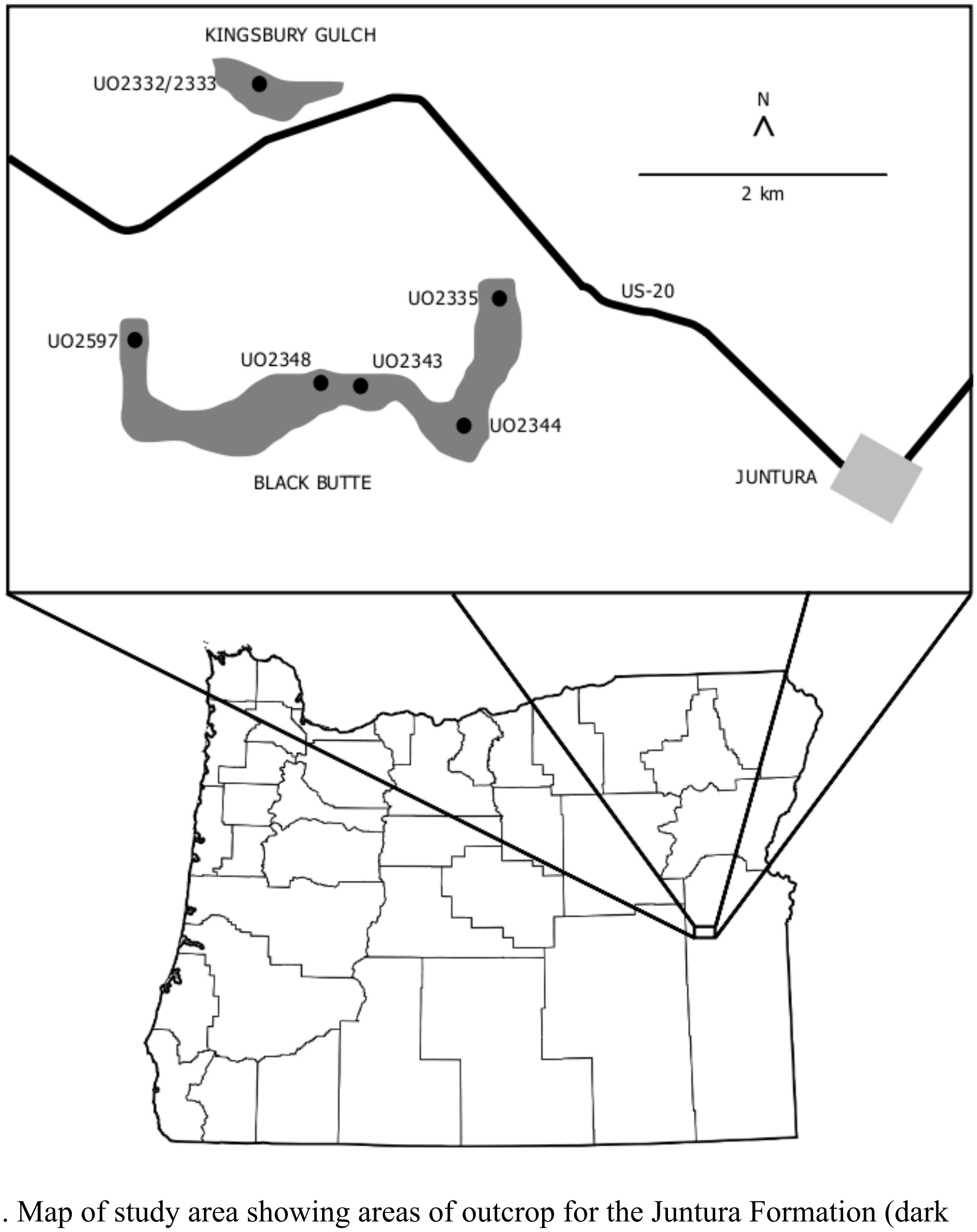

Figure 1. Map of study area showing areas of outcrop for the Juntura Formation (dark gray), location of the town of Juntura (light gray), and US Highway 20 (black line). Locations of sites are indicated by black circles. Scale bar equals two kilometers.

Systematic Paleontology

Class MAMMALIA Linnaeus 1758

Order CARNIVORA Bowdich 1821

Family CANIDAE Fischer de Waldheim 1817

Subfamily BOROPHAGINAE Simpson 1945

Tribe BOROPHAGINI Wang *et al.* 1999

Referred Specimens—UOMNH F-5538, partial P^4 from Black Butte (UO2344); UOMNH F-5652, partial premolar from Kingsbury Gulch (UO2333); UOMNH F-5653, C_1 from Kingsbury Gulch (UO2332); UOMNH F-5701, partial P^4 from Black Butte (UO2343); UOMNH F-6678, left metacarpal II from Black Butte (UO2337).

Description—Specimens F-5538, F-5652, and F-5701 are isolated premolars. They lack the shearing blades of felids (Turner & Antón 1997) and are morphologically similar to premolars of canids and amphicyonids. These premolars are not reduced as in amphicyonids (Hunt 1998), and as such may be assigned to the Canidae. The size of the teeth is consistent with one of the four large Late Clarendonian borophagin species (*Aelurodon taxoides*, *Epicyon saevus*, *E. haydeni*, and *Borophagus littoralis*; Table 1). These species can be distinguished largely on the basis of parastylid and protocone morphology (Wang *et al.* 1999). Because the anterior portions of these specimens are not preserved, Russell's (1956) assignation to *Aelurodon* must be overturned and teeth can only be assigned to the Borophagini.

	WP^4	LM^1	WM^1	LP_2	LP_3	LP_4	WP_4	LM_1	$TRWM_1$	$TLWM_1$	WM_2
C. crucidens	6.0	9.3	8.9	5.3	6.2	7.6	3.7	11.3	4.0	5.5	5.7
A. taxoides	13.0	17.0	19.9	13.1	15.5	19.2	11.0	30.1	11.8	10.3	9.1
P. euthos	8.1	12.7	14.5	7.0	8.1	10.5	5.8	20.3	7.4	7.8	6.4
C. robustus	9.5	13.7	16.9	8.1	9.6	13.1	7.9	23.8	9.2	9.2	7.8
E. saevus	11.5	17.5	20.3	9.3	11.3	16.8	10.0	29.1	11.4	10.7	8.9
E. haydeni	15.0	20.6	24.3	11.3	14.0	21.9	13.1	36.3	14.4	13.1	10.1
B. littoralis	10.6	16.6	19.3	8.4	9.9	16.1	9.5	26.5	10.8	10.1	8.8
UO F-2332	-	19.6	23.3	-	-	-	-	-	-	-	-
UO F-5701	11.8	-	-	-	-	-	-	-	-	-	-
UO F-42501	-	-	-	8.1	10.7	15.4	8.3	26.2	9.7	9.3	5.5
L. vafer	4.3	7.7	9.2	6.0	7.0	7.7	3.2	11.8	4.4	4.3	3.8
L. matthewi	4.6	8.4	10.5	6.4	7.4	8.1	3.4	13.1	5.0	4.9	4.2
M. macconnelli	4.8	8.4	9.7	6.1	7.0	8.3	3.4	12.4	4.5	4.7	4.2
E.? skinneri	-	-	-	7.0	8.4	9.0	4.0	14.8	6.3	6.0	-
UO F-5862	-	-	-	-	-	-	-	-	-	4.9	-

Table 1. Dental measurements of Juntura canids and comparative measurements of all known Late Clarendonian canids. Species measurements are species means from Wang *et al*. (1999) and Tedford *et al.* (2009). Gray cells represent Juntura Formation specimens.

Specimen F-5653 is an isolated canine. It is neither elongated nor sharpened enough to be attributed to a felid and lacks the characteristic "felid groove" (Martin 1998). Its small size precludes it being assigned to the Amphicyonidae (Hunt 1998). Canine teeth generally lack diagnostic features, but the lack of extreme recurvature indicates that the specimen does not represent *Cynarctus* (Wang *et al*. 1999). Within Clarendonian canids, its size is consistent only with large borophagins.

Specimen F-6678 is a second metacarpal from a medium-sized canid (Table 2). The specimen is consistent with the generalized borophagine description provided by Munthe (1989) in having a craniocaudally arched base, an articular surface with metacarpal III immediately distal to the lateral and medial edges of the base, a wide articular surface for trapezoid, two lateral facets for the magnum, a generally cylindrical (but slightly flattened distally) cross-section, a medially-curved shaft, and a cranially convex and caudally sharply keeled distal articular surface (Figure 2). It is also consistent with borophagine morphology in lacking a facet for the trapezium. The size of the metacarpal is consistent with the Late Clarendonian species *Cynarctus crucidens*, *Paratomarctus euthos,* and *Carpocyon robustus*. Because metacarpals have very few diagnostic features, it is impossible to assign F-6678 to a level below the Borophagini.

	LGlenoid	WGlenoid	LHumerus	WDEHumerus	WDASHumerus	L2Metacarpal	W2Metacarpal	L4Metacarpal
C. crucidens	-	-	150.0	27.0	20.0	-	-	-
A. taxoides	-	-	-	54.0	36.0	68.5	10.0	76.0
P. euthos	23.5	-	109.5	-	-	34.0	5.2	47.0
C. robustus	24.0	15.0	156.0	35.0	24.0	48.0	6.0	55.0
E. saevus	31.0	22.0	185.5	45.5	31.0	55.5	7.0	-
E. haydeni	54.0	37.0	264.3	64.6	41.1	89.0	14.0	84.5
UO F-5514	-	-	-	45.1	-	-	-	-
UO F-5938	23.5	15.6	155.0	37.4	24.3	-	-	50.0
UO F-6005	-	-	-	-	-	-	-	-
UO F-6678	-	-	-	-	-	47.7	6.4	-

	LIlium	LIschium	LPelvis	LFemur	WHFemur	WFemur	WDFemur	WPGFemur	LASCalcaneum
C. crucidens	-	-	-	-	-	-	-	-	-
A. taxoides	-	-	-	244.0	26.5	23.0	50.0	20.0	-
P. euthos	56.5	31.0	85.0	141.0	19.0	-	35.0	-	12.5
C. robustus	89.0	58.0	146.0	-	17.0	-	-	-	15.0
E. saevus	98.0	65.0	160.0	201.5	22.0	17.0	42.4	15.0	16.0
E. haydeni	105.0	71.0	175.0	260.7	29.2	23.0	54.8	19.8	21.5
UO F-5514	-	-	-	-	-	-	-	-	-
UO F-5938	80.0	50.0	136.0	180.0	18.6	13.2	33.9	13.2	-
UO F-6005	-	-	-	-	-	-	-	-	24.2
UO F-6678	-	-	-	-	-	-	-	-	-

Table 2. Postcranial measurements of Juntura borophagines and comparative measurements of all Late Clarendonian borophagines for which postcrania are available. Gray cells represent Juntura Formation specimens.

Figure 2. Postcrania of borophagines from the Juntura Formation. A, UOMNH F-6678, left metacarpal II in medial view, assigned to Borophagini; B, UOMNH F-5514, distal left humerus in cranial view, assigned to Borophagina; 1, entepicondylar foramen. Scale bar equals 1 cm.

Subtribe BOROPHAGINA Wang *et al*. 1999

Referred Specimen—UOMNH F-5514, distal left humerus fragment from Black Butte (UO2344); UOMNH F-5651, partial P^4 from Kingsbury Gulch (UO2333).

Description—The humerus (F-5514) is generally similar to that of F-5938 (*Carpocyon*) but is considerably larger. Despite its size, this humerus is relatively gracile and uncurved, traits that link it with borophaginans rather than aelurodontinans (Munthe 1989). Within borophaginans represented by postcrania, *Epicyon saevus* is most similar in size (Table 2). Further, the presence of an entepicondylar foramen suggests that specimen cannot be assigned to a derived species of *Borophagus*. However, basal members of *Borophagus* often retain entepicondylar foramina; due to a lack of postcranial material, it is unknown whether or not this feature is present in the Late Clarendonian *B. littoralis*. As such, the presence of an entepicondylar foramen in F-5514 does not rule out affinity with *Borophagus*.

The premolar (F-5651) was assigned by Russell (1956) to the now-invalid genus *Osteoborus*. The presence of a ridge connecting the parastyle and protocone indicates that the specimen represents a taxon from the Borophagina (Wang *et al*. 1999). Size of the specimen suggests that it can be attributed to *Epicyon* or *Borophagus littoralis*, but a more definite taxonomic assignation cannot be made.

CARPOCYON SP. Webb 1969

Referred Specimen—UOMNH F-5938, partial skeleton including fifth cervical vertebra, one thoracic vertebra, three lumbar vertebra including last lumbar vertebra, left iliac articular surface of sacrum, one caudal vertebra, 16 rib fragments, proximal scapula, right humerus, shaft of right ulna, proximal left metacarpal V, pelvis, right femur, and distal end of left femur, from Black Butte (UO2335).

Description—F-5938 was assigned to *Osteoborus* by Shotwell & Russell (1963). The specimen exhibits numerous traits characteristic of borophagines (Munthe 1989; Figure 3). The cervical vertebra has a dorsoventrally compressed centrum, a ventral keel on centrum, flattened surfaces of the prezygapophyses facing dorsally and slightly medially, flattened surfaces of the postzygapophyses facing ventrally and slightly laterally, knobs on the dorsomedial edge of the postzygapophyses, and subdivided transverse processes. The thoracic vertebra has a long, laterally compressed, caudally inclined, curved, and dorsally thickened spine, dorsally facing prezygapophyses, ventrally facing postzygapophyses, crescentic and concave articular surfaces for rib tubercles on the transverse processes, a shortened centrum, and concave rib facets at the lateral edges of the centrum. The lumbar vertebrae have short, broad, and cranially inclined spines, medially facing prezygapophyses, laterally facing postzygapophyses, caudally directed anapophyses decreasing in thickness in more caudal vertebrae, dorsocranially projecting metapophyses, craniolaterally and ventrally projecting ventral divisions of the transverse processes, and ventrally keeled centra. The last lumbar vertebra has broad postzygapophyses. The centrum of the caudal vertebra is dorsoventrally compressed. The ribs have flattened articular surfaces on the tubercles and convex articular surfaces on the heads. More cranial ribs are flattened in cross-section, while more caudal ribs are rounded. The scapula has a shallow, ovoid glenoid fossa, a slightly concave supraglenoid tuberosity, and a knob-like coracoid process. The humerus has a craniocaudally and mediolaterally convex head, an elongate lateral facet on projecting lesser tuberosity, a laterally compressed and distally rounded humeral shaft, a crest running from meeting of the deltoid and pectoral crests at the mid-humeral shaft to the distal articular surface, a roughened deltopectoral crest, an enlarged medial epicondyle with a protruding knob, four facets for flexor muscles and two for extensors, a reduced distal extensor facet, a distinct lateral epicondylar crest, a wide, obliquely-oriented articular surface, a keeled and distally deflected trochlea, and a perforated ulnar fossa. The ulna has a laterally compressed and distally rounded shaft and elongated scars for the adductor pollicis longus on the shaft. Metacarpal V has a craniocaudally-arched base, an articulation with metacarpal IV just distal to the medial edge of its base, an articular surface for the unciform, a swollen lateral surface of base, and a thickened proximal shaft. The pelvis has laterally-flaring ischia, a dorsally thickened iliac blade, a prominent iliac caudal dorsal spine, a large, rounded articular surface for sacrum extending onto the medial surface of the caudal dorsal spine, a large rectus femoris tuberosity, caudally thickened horizontal ischia, a large ischial tuberosity, a lateral ridge between the ischial spine and ischial tuberosity, an ischial spine level with caudal edge of the acetabulum, and a rounded, ventrocaudally facing acetabulum. The femur has a craniodorsally facing head, a dorsomedial fovea capitis, a craniocaudally expanded greater trochanter below the level of the head, middle gluteal facets, a transverse and elongate deep gluteal facet, a straight ridge connecting the greater trochanter and femoral head, a deep, medially-facing trochanteric fossa, a trochanteric ridge connecting the greater and lesser trochanters, a third trochanter slightly distal to the lesser trochanter, a flat and roughened cranial face between the third and lesser trochanters, a caudally concave and rounded shaft with some flattening caudally, a roughened area between proximally and distally diverging medial and lateral ridges, a cranially convex distal femoral shaft, a smooth medial articular condyle, a distinct proximal facet on the lateral condyle, distolateral facets on the lateral condyle, a lateral epicondyle that is more prominent and proximal than the medial epicondyle, a cranially and distally facing patellar groove, and a broad, rounded depression proximal to the patellar groove. Measurements indicate that F-5938 represents a medium sized borophagine consistent with *Cynarctus crucidens*, *Paratomarctus euthos*, or *Carpocyon robustus* (Table 2). The humerus and pelvis are more robust than in *P. euthos*. The scapula differs from *C. crucidens* in having an ovoid glenoid fossa and in lacking a knob-like supraglenoid tuberosity. The specimen shares several features with *C. robustus*, most notably a straight, gracile humerus, a large dorsal caudal iliac spine, and a gracile femur, and as such F-5938 may be assigned to *Carpocyon*. *Carpocyon robustus* is the only species of *Carpocyon* definitely present in the Late Clarendonian, but *C. webbi* has also been reported from Clarendonian faunas of indeterminate age (Wang et al. 1999). Because postcrania are lacking for this and other species of *Carpocyon*, this specimen cannot be definitely identified beyond genus level.

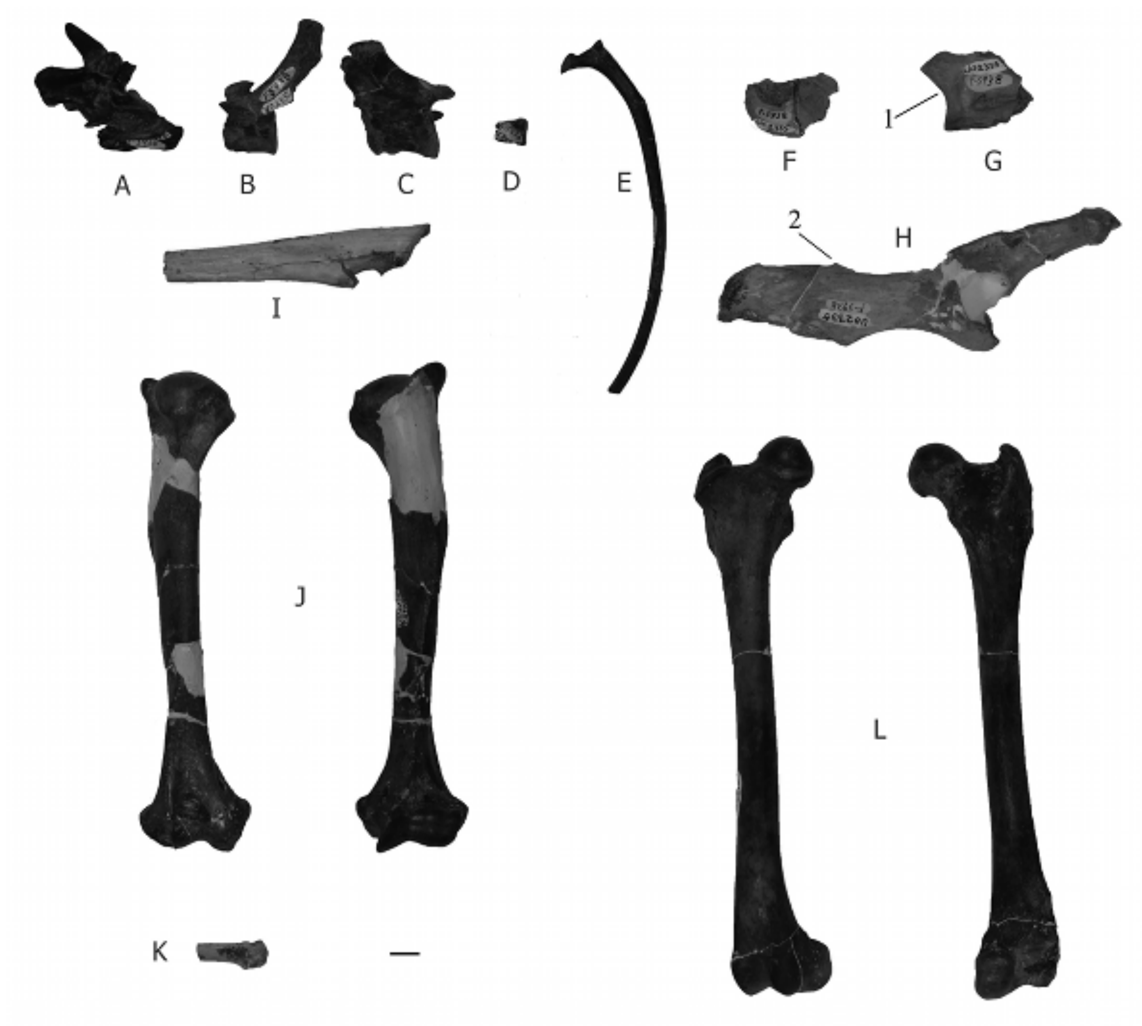

Figure 3. Postcrania of *Carpocyon* sp., UOMNH F-5938. A, Cervical vertebra in lateral view; B, Thoracic vertebra in lateral view; C, last lumbar vertebra in lateral view; D, caudal vertebra in dorsal view; E, left rib in cranial view; F, fragment of left sacrum in medial view; G, proximal scapula in lateral view; 1, glenoid fossa; H, left pelvis in lateral view; 2, dorsal caudal iliac spine; I, right ulna in lateral view; J, right humerus in caudal (left) and cranial (right) views; K, proximal left metacarpal V in dorsal view; L, right femur in cranial (left) and caudal (right) views. Scale bar equals 1 cm.

Discussion—The bones comprising F-5938 vary in color from white to very dark brown (Figure 3). Despite this, Russell (1956) and Shotwell and Russell (1963) state that all skeletal elements were found in one small quarry in association with one another, and as such represent one individual. This is confirmed by the size of the elements, all of which indicate a mid-sized borophagine (Table 2), the morphology of the different bones, all of which are consistent with *Carpocyon*, and the absence of any repeated elements (i.e. MNI=1). The differences in bone color are likely due to small-scale taphonomic effects, possibly reflecting different stages of weathering or exposure to water.

Russell (1956) lists several skeletal elements from F-5938 that are no longer stored with the specimen and could not be located for this study. These include both scapholunars, the distal end of a phalanx, metacarpal IV, and two fragments of distal ends of metapodials. Measurements of metacarpal IV were published by Shotwell and Russell (1963), and these have been included in Table 2 for comparative purposes. However, because no description or illustration of any of the missing elements was published, their morphology cannot be taken into consideration here.

EPICYON SAEVUS (Leidy 1858)

Referred Specimen—UOMNH F-42501, partial left dentary with roots of P_2–M_1 and broken M_2, from Black Butte (UO2597).

Description—F-42501 represents a large borophagine (*Aelurodon*, *Epicyon*, or *Borophagus*; Table 1). It can be assigned to the Borophagina based on the presence of an enlarged P_4 relative to the anterior premolars and M_1 (Figure 4). Further differs from aelurodontinans in lacking a reduced M_2. The premolars are relatively widely spaced, as in *Epicyon*. A relatively elongated talonid and shortened trigonid allow F-42501 to be assigned to *E. saevus*. The size of the specimen is consistent with this diagnosis.

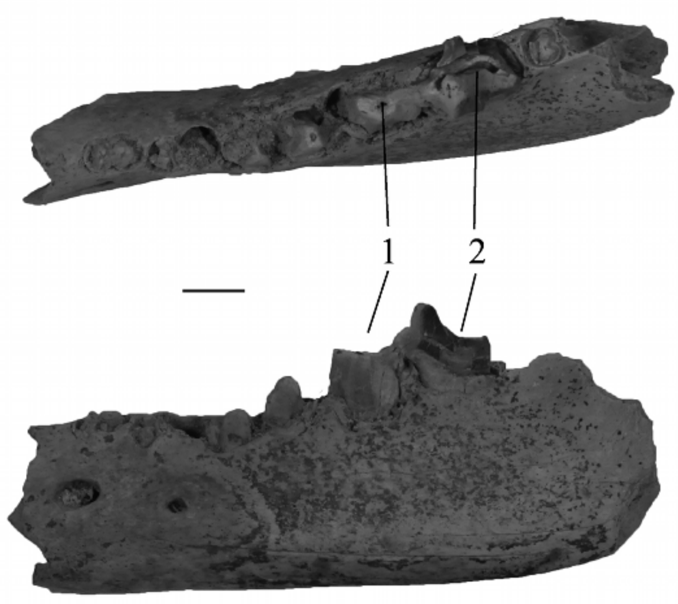

Figure 4. Dentary of *Epicyon saevus*. UOMNH F-42501 in occlusal (top) and lateral (bottom) views. 1, trigonid of M_1; 2, talonid of M_1. Scale bar equals 1 cm.

EPICYON HAYDENI Leidy, 1858

Referred Specimens—UOMNH F-5607, left M^1 from Kingsbury Gulch (UO2332); UOMNH F-6005, distal right calcaneum from Black Butte (UO2348).

Description—Shotwell & Russell (1963) identified F-5607 as *Aelurodon* sp. Its dental dimensions are consistent with larger species of that genus (Table 1), but the lingual cingulum, while not completely preserved, shows no evidence of being reduced anteriorly, a characteristic feature of *Aelurodon* (Wang *et al.* 1999; Figure 5). The specimen also shows no sign of being expanded anteriorly, a characteristic feature of derived species of *Borophagus*. The absence of a labial cingulum at the paracone allows F-5607 to be assigned to *Epicyon*. The absence of a narrowed talon indicates that the specimen represents a derived species, either *E. saevus* or *E. haydeni*. The size of the tooth is consistent with *E. haydeni*.

The calcaneum (F-6005) may be assigned to the Canidae on the basis of the morphology of the articular surfaces with the astragalus (Figure 5). The proximal half of the lateral articular surface is convex, distinguishing it from felids. The medial articulation is oriented proximo-distally, further distinguishing it from felids, but is not elongated as in many canines. The calcaneum does not exhibit any diagnostic morphology that would allow it to be assigned to particular species. However, it represents an individual comparable in size to *E. haydeni* and 34% larger than the mean for *E. saevus*, the next-largest species of Clarendonian canid (Table 2), making its assignment to the former species probable.

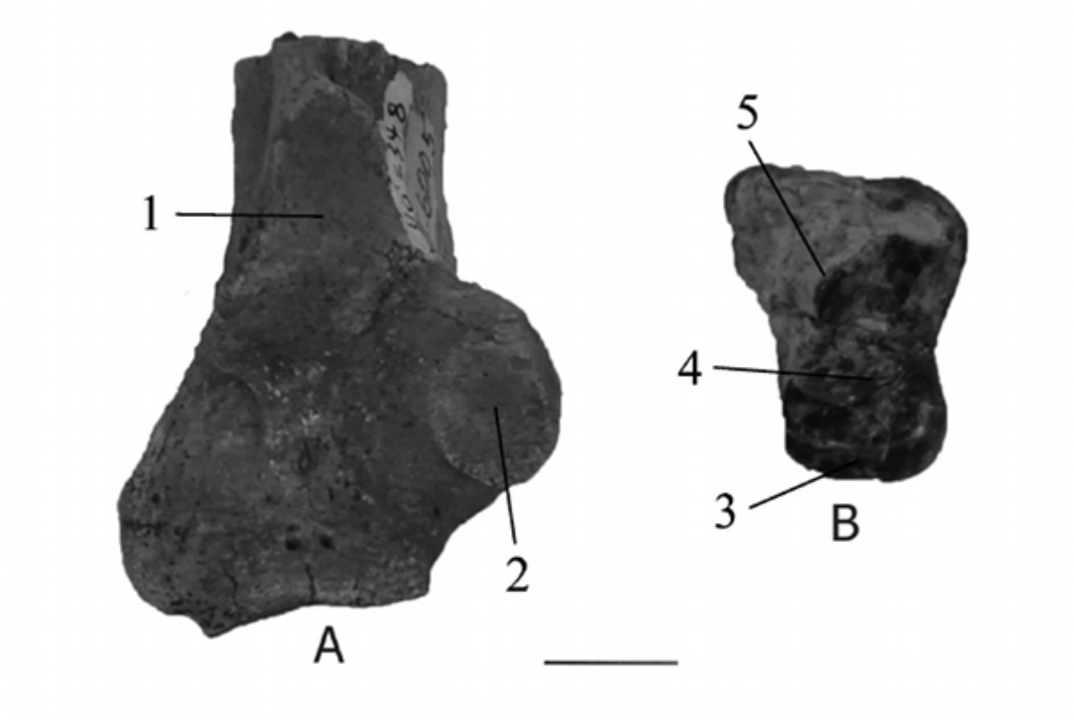

Figure 5. Postcrania of *Epicyon haydeni*. A, UOMNH F-6005, distal right calcaneum in cranial view; 1, lateral articular surface; 2, medial articular surface; B, UOMNH F-5607, M^1 in occlusal view; 3, lingual cingulum; 4, talon; 5, paracone. Scale bar equals 1 cm.

Subfamily CANINAE Fischer de Waldheim 1817

Referred Specimen—UOMNH F-5862, talonids of left and right M_1 and four tooth fragments, from Black Butte (UO2337).

Description—F-5862 was assigned to *Vulpes* by Shotwell & Russell (1963) on the basis of the presence of a bicuspate talonid (i.e. the transverse crest joining the hypoconid and entoconid is absent). While *Vulpes* does not appear until the Hemphillian, Clarendonian vulpins are represented by *Metalopex macconnelli* (Tedford *et al.* 2009). However, the absence of a transverse crest is also characteristic of most species of the basal canine *Leptocyon* and the basal canin *Eucyon*. Each of these genera is represented by at least one species in the Late Clarendonian. The length of the talonid is most similar to that of *Leptocyon matthewi*, though this is one of the few *Leptocyon* species to exhibit a transverse crest, making the Juntura specimen morphologically more similar to the smaller *L. vafer*. Relative width of talonid is an important character that can be used to distinguish canines from this interval; however, because the trigonid of both carnassials is missing and other teeth are represented only by incomplete and non-diagnostic material, it is impossible to address in this specimen. Until more material is uncovered, this specimen cannot confidently be assigned to any taxon more specific than Caninae.

Discussion

The structure of the Juntura canid fauna parallels that seen in other Late Clarendonian faunas in many regards. The smallest canids present are canines, though remains of these taxa are rare. In fact, the canine specimen described above is the only member of this subfamily to be reported from the Clarendonian of the northwest United States. This rarity is likely a genuine biological signal, as small mammals as well as large mammals are both well preserved and extensively sampled in the Juntura Formation (Shotwell & Russell 1963). This is in line with the continent-wide pattern observed by Tedford *et al.* (2009) and supports on a microcosmic scale their suggestion that canines remained rare until relatively recently and only radiated in the latest Miocene and onwards, concurrent with the extinction of larger borophagine canids.

Borophagines are well represented in the Juntura fauna. The majority of these are large taxa similar to, and in many cases referable to, *Epicyon*. However, at least in terms of body size, the Juntura borophagines remained relatively diverse; medium-sized borophagines were present, as demonstrated by the skeleton of *Carpocyon* and a metacarpal from a similarly sized individual of uncertain affinities. The presence of *Carpocyon* in the Juntura Formation marks a range extension for the genus, which is known from sites throughout the rest of western North America, but had not previously been reported in the Northwest (Wang *et al.* 1999).

All positively identified large-bodied borophagines from Juntura are species of *Epicyon*. This runs counter to the original assessment of the fauna by Russell (1956), in which he posited the presence of at least one species of the aelurodontinan *Aelurodon*. As with many late Miocene sites, two apparently sympatric species of *Epicyon* are present:

the large bodied *E. saevus* and the giant *E. haydeni* (Wang & Tedford 2008). Martin (1997) suggests that *Epicyon*-dominated faunas represent the second phase of a three-phase succession of large-bodied borophagines in the late Miocene of the Northwest (the first phase being dominated by *Aelurodon* and the third by *Borophagus*). The presence of *Epicyon* in Juntura and the lack of definite evidence of either of the other genera provide at least tentative support for this hypothesis that, if correct, could have important regional biostratigraphic implications. *Epicyon* has also been reported from the Chenoweth (Dalles) Formation of north-central Oregon (Wang *et al*. 1999) and the Ellensburg Formation of central Washington. While one locality within the Ellensburg Formation has been biostratigraphically dated to the Late Clarendonian (Martin & Pagnac 2009), it is unknown whether or not other sites within the formation are coeval, while the precise age of the Chenoweth Formation remains unknown. If Martin's hypothesis is correct, the presence of *Epicyon* may allow the assignation of sites in the region to the Late Clarendonian. Continued field work in the area will help resolve this and other questions regarding the canid fauna of the Northwest.

Descriptive projects such as this are the foundation of paleontology in general and of paleoecology in particular. Without a clear understanding of the phylogenetic, geological, and temporal context of a taxon, it is impossible to draw robust conclusions about that taxon's changing ecological role. This project and other studies of fossil canids (e.g. Wang 1994, Wang *et al*. 1999, Tedford *et al*. 2009) have provided a sufficiently strong foundation to make paleoecological analyses of the group possible, and for this reason canids – along with other well-studied families of mammals – are the ideal taxon in which to study ecological variables such as body size through time.

CHAPTER III

OLIGO-MIOCENE CLIMATE CHANGE AND MAMMAL BODY SIZE EVOLUTION IN THE NORTHWEST UNITED STATES

Introduction

One of the longest-standing ecological questions is how – or, indeed, whether – evolutionary patterns are shaped by climate. In fact, this question is as old as the science of ecology itself, as the influence of climate on plant biogeography was addressed by Humboldt and Bonpland (1807) in one of the field's foundational papers. In the subsequent two centuries, countless researchers have investigated the relationship between climate and biotic change, especially in recent years as the advent of anthropogenic global warming has made understanding such relationships all the more crucial. Despite their importance in predicting the effects of future climate change, models positing a relationship between climatic and biotic variables often remain subject to a great deal of debate. Even one of the earliest climatic hypotheses to be proposed is still undergoing significant revision; this hypothesis was first proposed by Bergmann (1847) as an explanation for latitudinal gradients in mammal body size and has borne his name ever since. In its original formulation, Bergmann's Rule holds that body size is driven by temperature: large taxa are favored in cold climates, such as those seen towards the poles, because their small surface area-to-volume ratios make them more effective at retaining heat, while smaller taxa are favored in warm climates, such as those seen towards the equator, because they are more effective at dispersing heat.

Bergmann's Rule has been tested numerous times in the century and a half since its original formulation. The latitudinal gradients observed by Bergmann have been confirmed in many mammal taxa (Ashton *et al*. 2000, Blackburn & Hawkins 2004, Meiri & Dayan 2003, Rodríguez *et al.* 2008) and have also been reported in birds (Ashton 2002b, Blackburn & Gaston 1996, James 1970, Meiri & Dayan 2003) and several taxa of poikilothermic animals (Ashton 2002a, Ashton & Feldman 2003, Lindsey 1966, Ray 1960); however, multiple alternative mechanisms have been proposed that may shape these patterns (Table 3). Many of these mechanisms, including Bergmann's Rule *sensu stricto*, hold that the physical environment, and in particular climate, drives body size evolution. Besides temperature, the two climatic variables most frequently associated with body mass are precipitation and seasonality. Like temperature, precipitation is generally higher in low-latitude ecosytems and has been suggested to show a negative correlation with body size, as large animals are thought to be able to store larger reserves of water, allowing them to survive periods of drought in dry environments (James 1970). Similarly, it has been suggested that large animals have greater capacity for energy reserves, allowing them to survive periods of famine in seasonal climates, which tend to predominate towards the poles, leading to a positive correlation between seasonality and body size (Millar & Hickling 1990). Another group of hypotheses posit the importance of biotic mechanisms. Agonistic interactions are among the most frequently cited potential drivers of body size evolution. Large size may confer an advantage to prey taxa by providing some protection against predators, and as such taxa in environments with high predation pressure might be expected to be larger than those that are preyed upon relatively infrequently (Korpimäki & Norrdahl 1989). The relationship between body size and competition is somewhat more complicated: Damuth (1993) found that island taxa, freed from competition, tended to evolve to an energetically efficient, medium-range body size, suggesting that increased competition may select for either increased or decreased body mass depending on the taxon in question. While both of these variables can be difficult to measure, it has long been recognized that richness increases towards the equator (Simpson 1964), and the increased abundance of potential predators and competitors in subtropical and tropical environments could lead to the appearance of body size gradients. Food availability is also hypothesized to have an influence on body size. For predatory taxa, the presence of large prey animals may select for larger individuals (Erlinge 1987), while the body size of herbivores often shows a positive correlation with primary productivity (Rosenzweig 1968). However, primary productivity tends to be highest at low latitudes, and thus should select for smaller animals towards the pole; this is the opposite of the pattern observed within most modern taxa.

While many refinements of and alternatives to Bergmann's Rule *sensu stricto* have been proposed, no consensus exists within the ecological community as to which hypothesis is most likely correct. This could be a consequence of the inherent complexity of natural systems: body size may be driven by a combination of factors and different taxa may respond differently to the same stimuli. Alternatively, it could be a product of the data that have been used to examine body size evolution: neontological data are plentiful and relatively easily controlled, but are not without their drawbacks. Modern ecological data have been culled from an interval that represents a relatively narrow range of climatic conditions (Berteaux *et al*. 2006) during which climatic variables tend to be tightly correlated. Predicting biotic responses to climatic regimes differing from those of the previous few decades, therefore, requires extrapolating well beyond the range of observed conditions. Further, neontological data by definition cannot be used to address trends through time. Both of these concerns can be addressed by substituting time for space through the use of paleontological and paleoecological data. Given a well-sampled fossil record, robust estimates of body mass or well-established proxies for size, and detailed paleoclimatic records, such data make it possible to observe biotic responses to large-scale climate change, to tease apart ecological variables that are tightly correlated in modern ecosystems, and to visualize trends through time, providing an extra dimension to ecological analyses.

Variable	**Expected Correlation With Body Mass**	**Explanation**
Temperature	-	Large body size allows animals to retain heat more efficiently
Precipitation	-	Large body size allows animals to harbor greater water reserves
Seasonality	+	Large size allows animals to harbor greater energy reserves
Predation Pressure	+	Large size makes animals more resistant to predation
Competition	?	Competition forces animals away from an optimal body size
Prey Size	+	Large predators are better equipped to hunt larger prey
Primary Productivity	+	Productive ecosystems can support larger animals

Table 3. Predictions of different body mass hypotheses. Plus sign indicates a positive relationship with body mass, minus sign indicates a negative relationship with body mass, and question mark indicates a relationship that varies based on size.

The influence of climate on mammalian biotic change through time has been the focus of several paleobiological studies, though these have predominantly addressed diversity rather than body mass evolution. The results of this research have been somewhat ambiguous, with some researchers (e.g. Barnosky 2001, Barnosky *et al*. 2003, Retallack 2007) finding a correlation between climate and diversity and others (e.g. Alroy *et al.* 2000, Prothero 1999, Rose *et al*. 2011) finding no predictable relationship between the two variables. Body size in Cenozoic mammals is also a rich area of study, but until recently the field has primarily centered on body mass trends within groups, and in particular on Cope's Rule, the hypothesis that taxa within lineages tend to increase in size with time (e.g. Alroy 1998, Gould & MacFadden 2004, Van Valkenburgh *et al*. 2004). One of the first paleontological studies to address Bergmann's Rule in pre-Pleistocene mammals was conducted by Gingerich (2003), who observed brief but significant decreases in body size in the condylarths *Ectocion* and *Copecion* as well as the perissodactyl *Hyracotherium* during the Paleocene-Eocene Thermal Maximum (PETM) in northwest Wyoming. While Gingerich acknowledged that climate likely played a role in this temporary dwarfing, he suggested that the magnitude of body size change was too large to be explained by temperature alone. More recently, Smith *et al*. (2010) analyzed maximum body mass in mammals at a continental to global scale between the Cretaceous and Recent. The authors compared their body size data with several abiotic factors, including climate, and found a significant correlation between temperature and body mass. While this result seems to support Bergmann's Rule, it is far from conclusive. Bergmann's Rule and all its corollaries are predicated on the observation that body mass shows considerable geographic variation, and is thus highly susceptible to local to regional environmental variability; such local signals are likely to be lost when analyzing data at the continental level. Because of this, any effort to observe the connection between climate and body size in the fossil record must be conducted at a finer geographic scale.

In order to carry out a localized paleoecological test of Bergmann's Rule and its climatic corollaries, we have reconstructed body size trends for three Oligo-Miocene mammal taxa in the Northwest United States, a region unusual for the high quality of both its fossil and paleoclimatic records. As climatic variables fluctuate through time, Bergmann's Rule and its corollaries make specific predictions about how body size should respond. Bergmann's Rule *sensu stricto* predicts that body size should track temperature through time, with small taxa predominating during periods of global warming and larger taxa predominating in cooler conditions. If either of the other climatic hypotheses is correct, however, larger taxa should be prevalent during periods of decreased rainfall or increased seasonality. The three models discussed above not only predict the direction of the relationship between a climatic variable and body size, they predict the relative magnitude of change as well: a major change in temperature, precipitation, or seasonality should drive a comparably large change in body mass, while taxa should not change significantly in size during periods of climatic stasis.

Methods

Scope of Project & Paleoclimatic Proxies

The temporal scope of this project is the Arikareean-Hemphillian North American Land Mammal Ages (late Oligocene-earliest Pliocene, 30-5 Ma; Tedford *et al.* 2004). This interval is an ideal one in which to study the relationship between climate and body mass, both because of its excellent mammal fossil record and because it encompasses considerable fluctuation in global temperature (Zachos *et al.* 2001). This fluctuation includes both intervals of global warming (e.g. Late Oligocene warming, 26-24 Ma; Mid-Miocene Climatic Optimum, MMCO, 17-15 Ma) and of global cooling (e.g. Oligo-Miocene glaciation, 24 Ma; Late Miocene cooling, 15-5 Ma).

Previous analyses of mammal body size through time have focused primarily on phylogenetic body mass trends (e.g. Alroy 1998, Alroy 2003, Gould & MacFadden 2004), and in consequence have been conducted at a continental scale. Because this study addresses the relationship between body size and climate and because climate can vary considerably on a local scale, it was conducted within a single biogeographic region: the Northwest United States (the Columbia Plateau faunal province of Tedford *et al.* 2004), which encompasses primarily sites from eastern Oregon but also includes faunas from southern Washington, southeast Idaho, and northern Nevada (Figure 6). The region's fossil record is both rich and nearly continuous over the course of the Arikareean-Hemphillian interval. Many of these faunas, such as those from the Arikareean-Hemphillian beds of the John Day Basin, the Barstovian-Hemphillian formations of Oregon's Juntura Basin and Nevada's Virgin Valley, and the Clarendonian-

Hemphillian beds along the Columbia River in Oregon and Washington, have been extensively collected and studied.

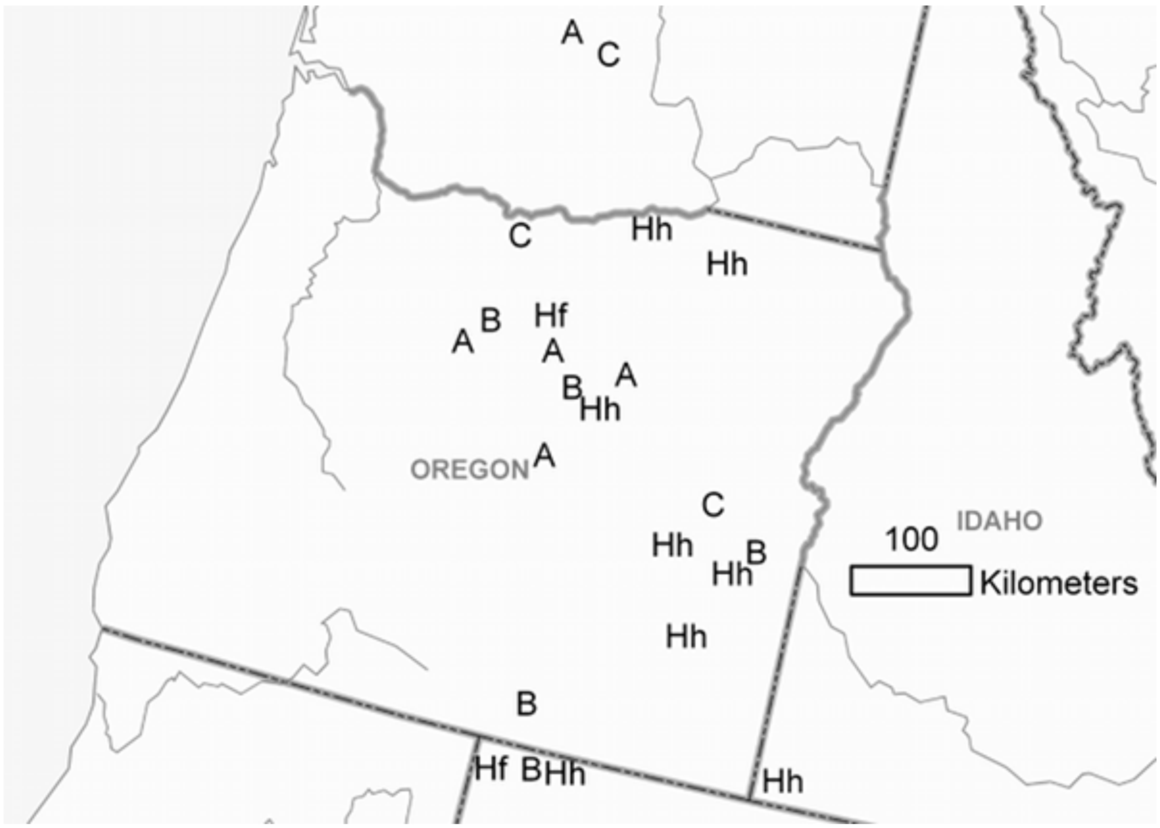

Figure 6. Map of study area and approximate location of sites included. A = Arikareean NALMA; Hf = Hemingfordian NALMA; B = Barstovian NALMA; C = Clarendonian NALMA; Hh = Hemphillian NALMA.

Besides a well-studied and fairly complete fossil record, the Northwest is also remarkable for its detailed record of regional climate. This record is derived primarily from climofunctions based on the physical and chemical characteristics of paleosols. Sheldon *et al*. (2002) established relationships between the chemical index of alteration without potassium and mean annual temperature and between the molar ratio of bases to alumina and mean annual precipitation, while Retallack (2005) demonstrated that mean annual range of precipitation (a measurement of seasonality) can be estimated from the thickness of carbonate nodule-bearing horizons of soils. Retallack (2007) collected data from Cenozoic paleosols from sites throughout eastern Oregon to reconstruct regional trends in temperature, precipitation, and seasonality. Because climate data are not available for sites from surrounding states, we have used the eastern Oregon data as a proxy for climate throughout the Northwest. The robustness of paleopedological climofunctions has frequently been called into question (e.g. Royer 1999) and similar studies often rely on isotopic proxies for climate (e.g. Rose *et al*. 2011). However, two aspects of the paleopedological record have led to its inclusion here. First, the chemical assays developed by Sheldon *et al*. have a more robust relationship with temperature and precipitation than do many paleopedological proxies for climate. Second, the paleosol record of eastern Oregon is extremely well sampled; the database used in this study encompasses 113 samples. Many of these samples were collected at sites that have also yielded extensive mammalian fossil material, allowing site-specific trends in climate and body mass to be observed.

Body Mass Estimation

The size of the Northwest fossil record is sufficiently large to make an analysis of body size trends in all mammals impractical. We have chosen to focus on three well-represented families of mammals: equids, canids, and sciurids. Each group distinct from the other two in terms of size, diet, and ecology; in fact, each represents one of the poles of Schad's (1977; modified by Retallack 2004b) ternary model of animal lifestyles (equids are large, herbivorous "metabolic-limb" specialists, canids are mid-sized, carnivorous "respiratory-circulatory" specialists, and sciurids are small, granivorous "nerve-sense" specialists). Because these families each exhibit differing ecologies, any body size trend apparent in all three may reasonably be presumed to represent an ecosystem-wide signal. Further, robust taxonomic frameworks exist for all three families (Goodwin 2008, MacFadden 1992, Wang & Tedford 2008), making observations of trends at many taxonomic levels possible.

For each of the three families to be considered, a well-established relationship between dental dimensions and body mass has been established. Sciurid body mass may be estimated from the length of the lower tooth row (Hopkins 2007); however, there are relatively few sciurid specimens that preserve the entire lower tooth row, so first lower molar length is used as a body mass proxy instead, as first lower molar size has been shown to be a good proxy for body size across all mammals, provided that the study is taxonomically constrained (Creighton 1980). Canid body mass is correlated with the antero-posterior length of the first lower molar (the lower carnassial; Van Valkenburgh 1990). In both these taxa, body size is correlated with just one dental variable, allowing that variable to be used directly as a proxy for mass without conversion; because the data are not transformed through a regression, the use of a single proxy reduces the amount of error in the analysis. Equid body size is based on the regressions developed by Janis (1990) for perissodactyls and hyracoids using the length of any lower cheek tooth or second upper molars. Because multiple body mass regressions exist for equids, body mass was calculated in order to include the largest number of specimens possible.

Only specimens already collected and catalogued in museum and university collections were measured. Data are derived from surveys of the collections at the American Museum of Natural History (AMNH), Idaho Museum of Natural History (IMNH), John Day Fossil Beds National Monument (JODA), Natural History Museum of Los Angeles County (LACM), Sierra College Natural History Museum (SCNHM), South Dakota School of Mines and Technology (SDSMT), University of California Museum of Paleontology (UCMP), University of Oregon Museum of Natural and Cultural History (UOMNH), and University of Washington Burke Museum (UWBM). Some intervals (e.g. the Hemingfordian) were underrepresented in the collections visited; these areas of the data set were augmented by including published measurements of specimens from collections that were not visited. Measurements were made using Mitutoyo Absolute Digimatic Calipers. In total, 67 sciurid specimens, 66 canid specimens, and 230 equid specimens were included in the database; more precise details about the specimens used is available in the supplementary material.

Analysis

The most straightforward qualitative method for comparing body mass trends to climatic fluctuation is to plot visual representations of both variables through time. In order to do so, body size and paleoclimate data were binned into North American Land Mammal Age (NALMA) subdivisions (Tedford *et al.* 2004) and were plotted using Microsoft Excel. Land mammal ages were used as bins in preference to million-year intervals due to the imprecision in dating of many sites; only 68 of the 410 published mammal-bearing localities in Oregon (17%) have been dated using isotopic methods, while localities in surrounding states are even more dependent on biostratigraphic dates (Carrasco *et al*. 2005). As such, it is impossible to assign the overwhelming majority of the sites included in this study to finer bins than NALMA subdivisions. Body size profiles were constructed for all families, subfamilies, tribes, subtribes, genera, and species that were present in more than one temporal bin.

We tested whether body mass was correlated with the three climatic variables by running two sets of multiple linear regressions in JMP. In the first, both body mass and paleoclimatic data were binned into land mammal age subdivisions. Only the 19 taxa that were present in three or more bins could be included in this portion of the study. These taxa included all three families as well as five subfamilies, five tribes, five genera, and one species (Table 4). In order to address the concern that binning body mass and climate into temporal intervals might dampen any fine-scale ecological signal, a second set of regressions was run comparing site-specific variables. This reduced the sample size to seven sites (Bone Creek, Mascall, Black Butte, Ironside, McKay, Rattlesnake, and Rome) and six taxa (three families, one subfamily, and two tribes; Table 5), but allows the analysis of trends within a framework that is tightly constrained both temporally and geographically. Whether or not body size trends within taxa conformed to the predictions made by Bergmann's Rule and its corollaries was determined using a sign test on the direction of each regression.

Hypotheses positing a connection between climate and body size predict not only the directionality of body size change, but the magnitude of that change as well, as large changes in climate should be associated with large changes in body mass. In order to test these predictions, the magnitude of body size change between NALMA subdivisions was calculated by computing first differences in mean body mass for 12 family- to genus-level taxa between bins (Table 6). While first differences were always calculated for two sequential bins, not all units contain data, so in some cases these bins were separated by a gap of three or fewer NALMA subdivisions. First differences between the same bins were also calculated for the three climatic variables. The magnitude of climate change was then regressed against the magnitude of body size change for the 12 different taxa.

Results

Body size trends vary widely between the three families included in this study (Figures 7-9). Mean sciurid body mass remains roughly constant throughout the Oligo-Miocene, with a spike in the Early Early Hemphillian. Equid body mass is static through the Arikareean but begins steadily increasing in the mid-Miocene. Canid body mass is somewhat more chaotic, with periods of both increasing and decreasing size. In no case does body mass closely track any climatic variable.

Only four taxa were found to have a statistically significant correlation with climate at a regional level (significant positive relationships were found to exist between temperature and body mass in 'anchitheriine' horses and between precipitation and body mass in the equid *Archaeohippus*, while negative relationships exists between seasonality and body mass in *Protospermophilus* and Caninae; Figure 10, Table 4). The site-specific data yielded only two significant relationships (positive correlations between sciurid body mass and temperature and between canid body mass and precipitation; Figure 11, Table 5). In five of the six cases, the direction of the relationship was the opposite of what would be predicted by Bergmann's Rule and its corollaries; only Caninae showed the expected positive relationship with seasonality. For the regional data, only 46% of the regressions yielded a result in keeping with the predictions made by Bergmann's Rule and other climatic hypotheses; this number rises to only 63% in the site-specific data. In all cases the sign test fails to support a significant departure from a random distribution. Regression of body mass against climatic first differences did not yield any significant correlations (Table 6), nor did the distribution of the signs of the correlations differ significantly from a random distribution.

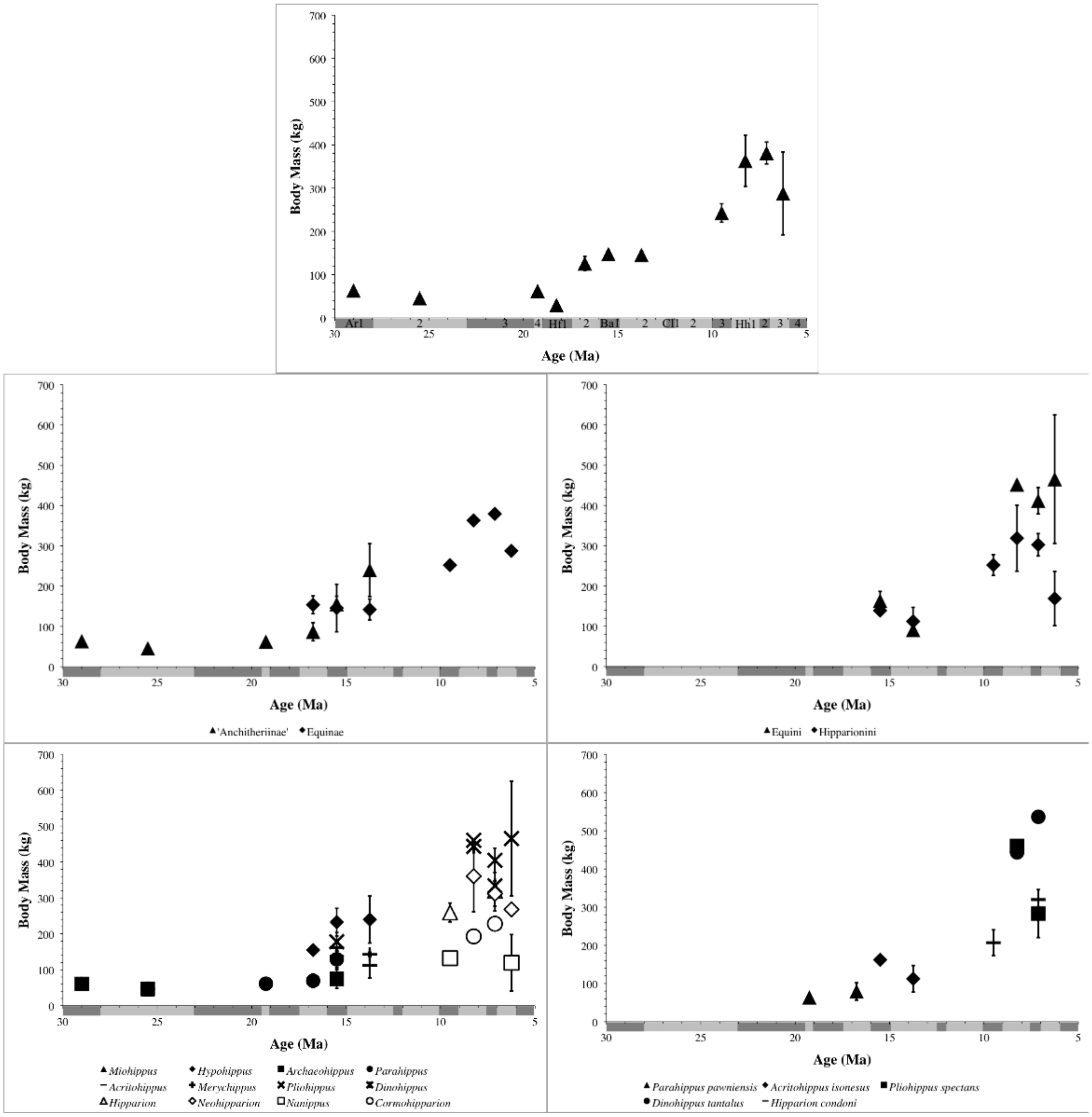

Figure 7. Mean equid body size in the Northwest United Sates through the Arikareean-Hemphillian interval. From top left to bottom right charts show body mass at family, subfamily, tribe, genus, and species levels. Error bars represent one standard error. Shaded boxes along x-axes represent Arikareean (Ar), Hemingfordian (Hf), Barstovian (Ba), Clarendonian (Cl), and Hemphillian (Hh) NALMA subdivisions (after Tedford *et al*. 2004).

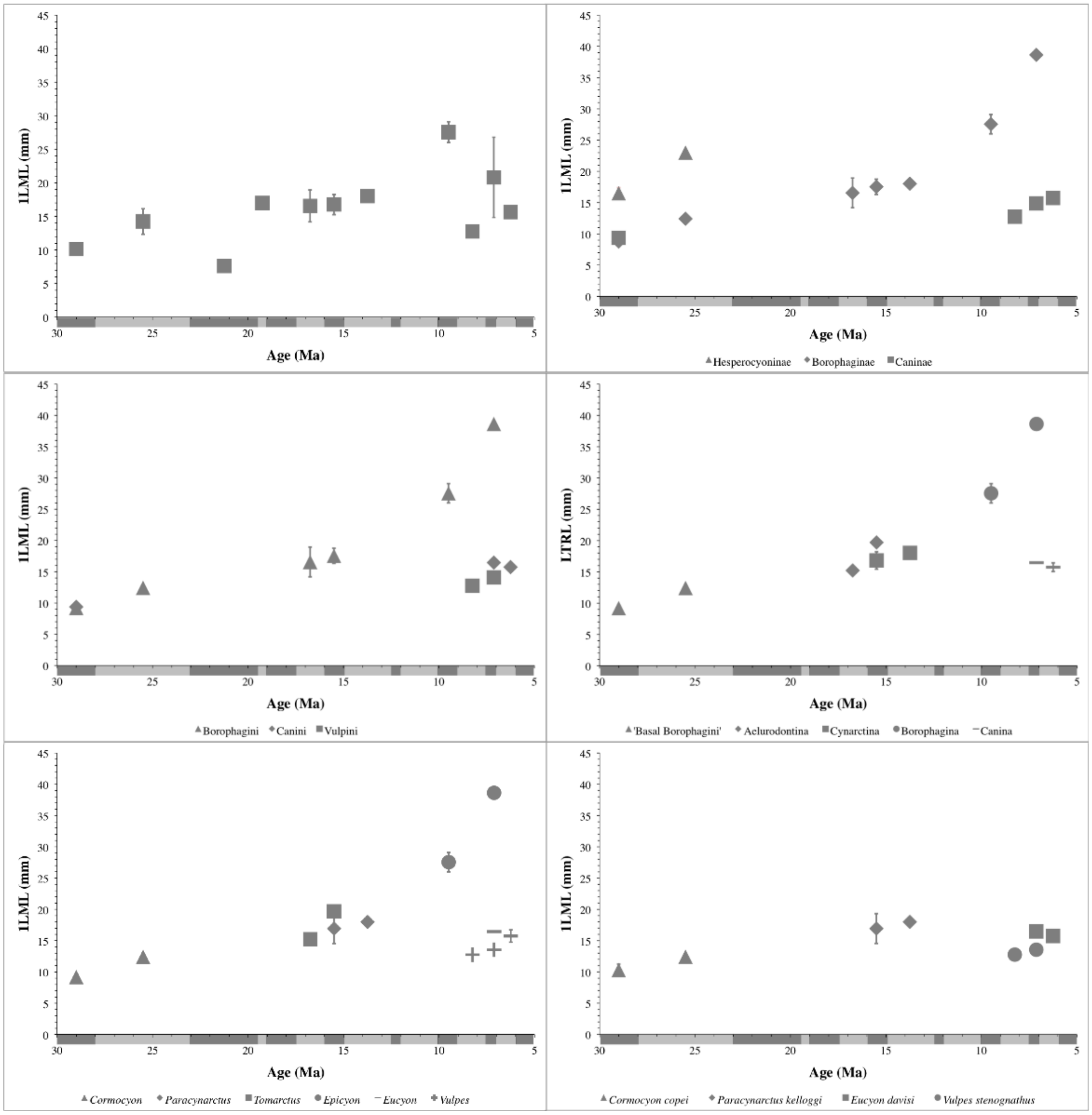

Figure 8. Mean canid body size in the Northwest United Sates through the Arikareean-Hemphillian interval. From top left to bottom right charts show body mass at family, subfamily, tribe, subtribe, genus, and species levels. Error bars represent one standard error. Shaded boxes along x-axes represent Arikareean (Ar), Hemingfordian (Hf), Barstovian (Ba), Clarendonian (Cl), and Hemphillian (Hh) NALMA subdivisions (after Tedford *et al*. 2004).

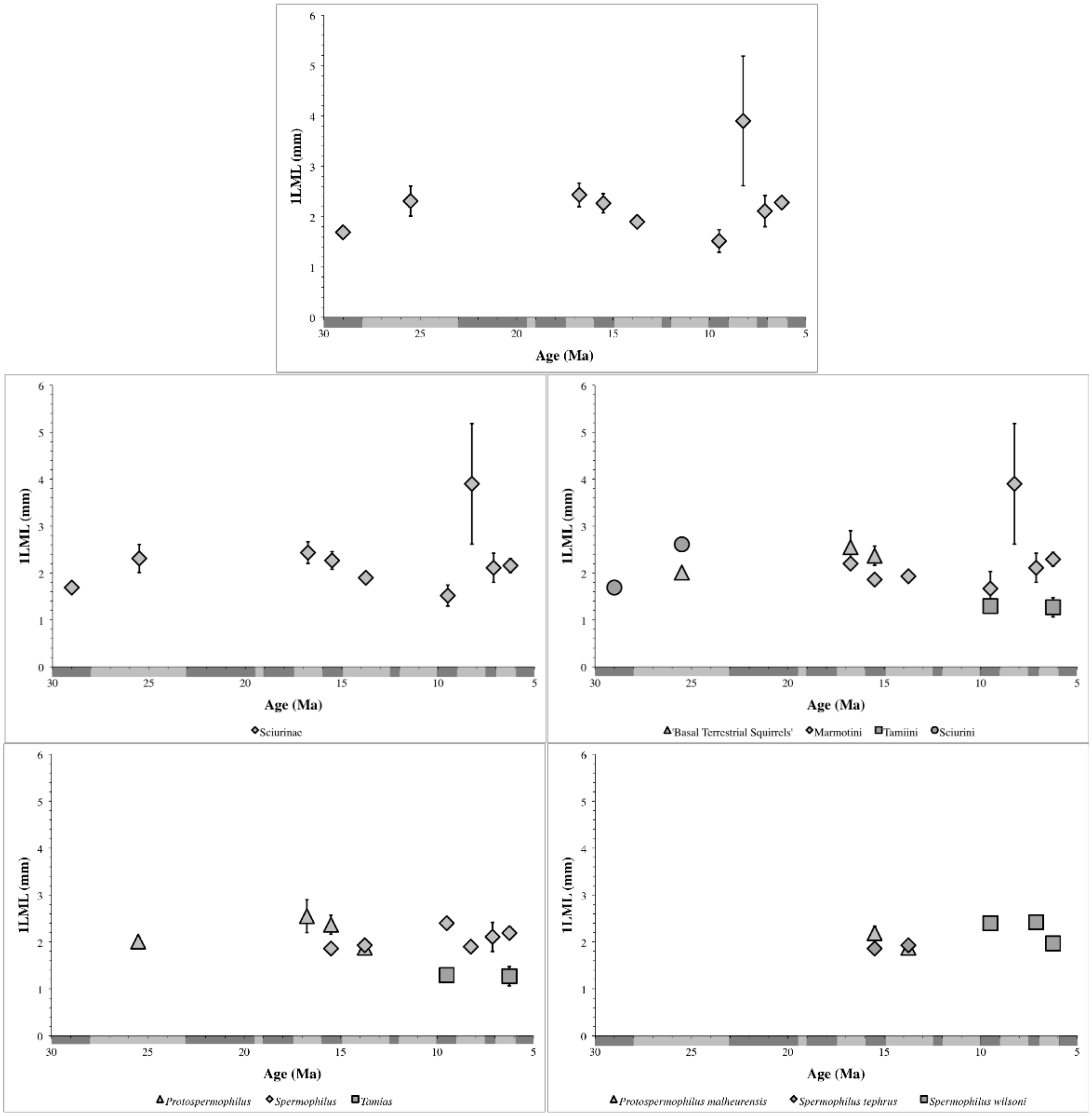

Figure 9. Mean sciurid body size in the Northwest United Sates through the Arikareean-Hemphillian interval. From top left to bottom right charts show body mass at family, subfamily, tribe, genus, and species levels. Error bars represent one standard error. Shaded boxes along x-axes represent Arikareean (Ar), Hemingfordian (Hf), Barstovian (Ba), Clarendonian (Cl), and Hemphillian (Hh) NALMA subdivisions (after Tedford *et al*. 2004).

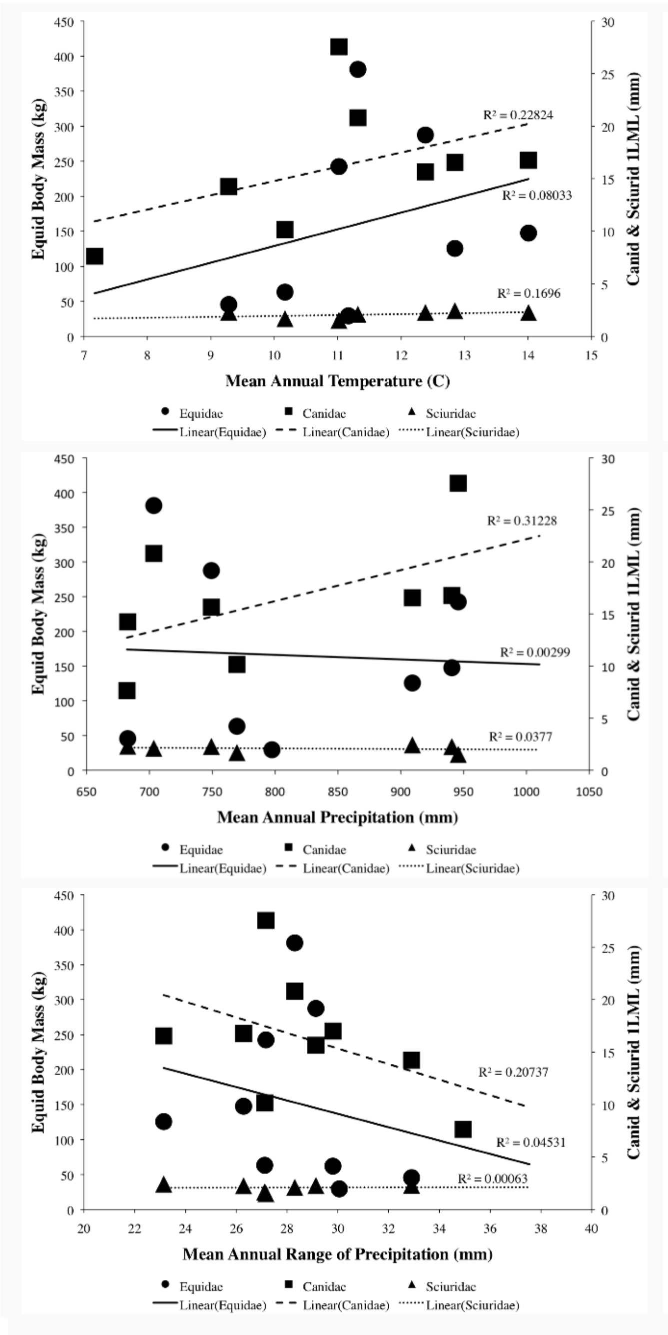

Figure 10. Correlations between body mass and regional climatic variables at the family level. From top to bottom, charts represent temperature, precipitation, and seasonality. R^2 values are displayed on charts. 1LML = first lower molar length.

	Temperature (-)		Precipitation (-)		Seasonality (+)	
	Slope	Significance	Slope	Significance	Slope	Significance
Sciuridae	0.09	0.36	-0.0006	0.68	0.003	0.96
Sciurinae	0.08	0.38	-0.0005	0.72	-0.0004	0.99
Marmotini	0.04	0.78	-0.001	0.22	0.003	0.97
Protospermophilus	0.09	0.37	0.002	0.29	-0.06	0.01
Spermophilus	-0.14	0.14	-0.00003	0.99	0.07	0.63
S. wilsoni	-0.34	0.16	0.0006	0.81	-0.20	0.42
Canidae	1.47	0.18	0.03	0.12	-0.64	0.29
Borophaginae	1.61	0.60	0.004	0.93	-0.05	0.98
Borophagini	1.56	0.61	0.004	0.93	-0.06	0.97
Caninae	3.07	0.05	-0.08	0.27	3.39	0.03
Canini	3.22	0.12	-0.11	0.16	3.60	0.09
Equidae	28.61	0.37	-0.02	0.97	-7.95	0.63
Anchitheriinae	19.65	0.03	0.35	0.05	-6.07	0.30
Archaeohippus	4.87	0.09	0.10	0.03	-3.25	0.12
Parahippus	14.60	0.35	0.23	0.43	-4.16	0.51
Equinae	-61.30	0.14	-0.72	0.07	32.09	0.13
Hipparionini	-48.69	0.12	-0.24	0.60	15.78	0.74
Equini	-100.05	0.36	-1.20	0.22	109.18	0.08
Pliohippus	-91.91	0.39	-1.12	0.24	102.97	0.06

Table 4. Direction and significance of correlations between climate and mammal body mass at a regional scale (data binned into NALMA subdivisions). Columns indicate slope and significance (p-value) of the relationship. Shaded cells indicate significant relationships ($p < 0.05$). Plus and minus signs in parentheses after climatic variables indicate directionality predicted by Bergmann's Rule and its corollaries.

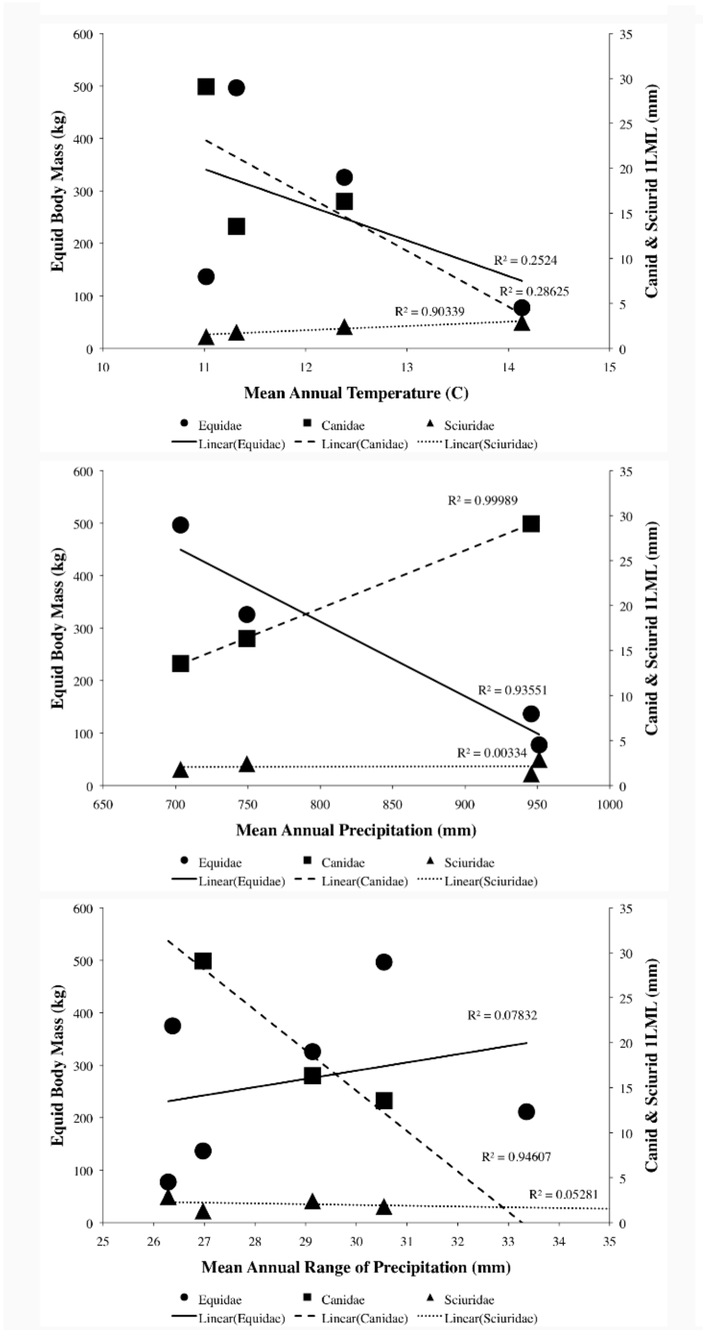

Figure 11. Correlations between body mass and site-specific climatic variables at the family level. From top to bottom, charts represent temperature, precipitation, and seasonality. R^2 values are displayed on charts. 1LML = first lower molar length.

	Temperature (-)		Precipitation (-)		Seasonality (+)	
	Slope	**p-value**	**Slope**	**p-value**	**Slope**	**p-value**
Sciuridae	0.47	0.05	0.0003	0.94	-0.08	0.77
Marmotini	0.88	0.12	-0.003	0.53	0.18	0.67
Canidae	-6.19	0.64	0.06	0.007	-4.48	0.15
Equidae	-23.49	0.73	-0.26	0.73	2.59	0.90
Equinae	-53.46	0.41	-0.73	0.30	37.08	0.05
Hipparionini	[redacted]				50.63	0.10

Table 5. Site-specific direction and significance of correlations between climate and mammal body mass. Columns indicate slope and significance (p-value) of the relationship. Shaded cells indicate significant relationships (p < 0.05). Shaded cells indicate significant relationships (p < 0.05). Plus and minus signs in parentheses after climatic variables indicate directionality predicted by Bergmann's Rule and its corollaries.

	Temperature (-)		Precipitation (-)		Seasonality (+)	
	Slope	**p-value**	**Slope**	**p-value**	**Slope**	**p-value**
Sciuridae	0.13	0.37	-0.001	0.40	0.03	0.55
Sciurinae	0.12	0.41	-0.001	0.38	0.03	0.56
Marmotini	0.05	0.75	-0.002	0.26	-0.008	0.95
Spermophilus	-0.15	0.41	0.002	0.46	-0.23	0.24
Canidae	0.41	0.73	0.03	0.25	-0.32	0.65
Borophaginae	-0.88	0.40	-0.01	0.36	-0.01	0.98
Borophagini	-0.86	0.42	-0.01	0.38	-0.03	0.95
Equidae	-13.40	0.54	-0.27	0.35	-6.32	0.45
Anchitheriinae	[redacted]				-0.84	0.86
Parahippus	[redacted]				5.5	0.17
Equinae	-32.46	0.38	-0.53	0.30	-17.33	0.81
Hipparionini	-48.36	0.40	-0.33	0.74	325.79	0.73

Table 6. Direction and significance of correlations between climate and mammal body size first differences. Columns indicate slope and significance (p-value) of the relationship. Note that no correlation is significant ($p < 0.05$). Plus and minus signs in parentheses after climatic variables indicate directionality predicted by Bergmann's Rule and its corollaries.

Discussion

The results presented here do not support Bergmann's Rule and its climatic corollaries: there is no evidence for a causal link between any one climatic variable and mammal body size evolution during the Oligo-Miocene. Some significant correlations between climate and body mass were found, but in almost all cases the direction of the relationship was the opposite of what had been predicted. A certain number of false positives are to be expected when running numerous statistical tests (Gotelli & Ellison 2004), and it is likely that these relationships fall into this category rather than representing actual ecological patterns, a suggestion supported by the results of the Bonferonni Correction for the number of tests run. After applying the correction, only the relationship between site-specific canid mass and precipitation remains statistically significant, and even this correlation is unlikely to represent a causal relationship as the precipitation hypothesis predicts a negative relationship, while the correlation found here is positive. The precipitation and seasonality hypotheses are borne out by the data more often than is Bergmann's Rule *sensu stricto*, but in no case does the distribution of expected and unexpected results depart significantly from random and as such these patterns do not imply a causal relationship between climate and body mass.

The body size profiles plotted for taxa from eastern Oregon and surrounding states further refute the suggestion that any one climatic variable predictably drives body size evolution in all mammals. Not only do none of these profiles closely track temperature, but all show extremely different patterns, reflecting the absence of an ecosystem-wide signal. Some of the patterns presented here parallel those observed at the continental scale and may suggest alternative drivers of body size evolution. Fossil horses are the classic example of Cope's rule, as they show an increase in body size during the course of the Cenozoic, though as Gould & MacFadden (2004) observe, this reflects the evolution of large body size in several different lineages rather than a family-wide tendency towards larger taxa. This size increase, as well as a concurrent increase in body size variation, is visible in horses from the Northwest beginning in the mid-Miocene, but is preceded by a period of stasis: from the earliest Arikareean through the end of the Hemingfordian, equids (which are represented during that interval solely by 'anchitheriines') do not undergo a significant change in size. The size increase observed beginning in the Barstovian is delayed relative to horses in North America at a continental scale (MacFadden 1986) and is roughly coincident with the breakup of woodland habitats after the MMCO (~16 Ma; Zachos *et al*. 2001). Woodland habitats had begun to give way to grasslands during the early Arikareean in the Northwest, but rebounded more strongly in the region than elsewhere in North America during the MMCO (Retallack 2007), possibly explaining the delayed increase in equid body mass. This suggests that, instead of being driven primarily by one climatic variable, horse body size evolution has been influenced by large-scale environmental change, with more open habitats favoring the evolution of larger taxa within several different lineages.

Canid body mass also follows patterns similar to those observed at larger scales. The family-level body size profile appears chaotic, but clearer trends become apparent at lower taxonomic levels. All three subfamilies of canids (Hesperocyoninae, Borophaginae, and Caninae) are present in the Northwest at the beginning of the Arikareean-Hemphillian interval as members of central Oregon's John Day fauna. Hesperocyonines are represented by the large-bodied *Enhydrocyon, Paraenhydrcyon*, and

Mesocyon, while both the Borophaginae and Caninae are represented by much smaller taxa. Hesperocyonines disappear from the Northwestern fossil record after the mid-Arikareean, at which point borophagines expand in both diversity and size. Van Valkenburgh *et al*. (2004) observed a Cope's rule-like pattern in borophagines on a continental scale, and this trend appears also to be present within the Northwest, as members of this subfamily increase in size during each land mammal age subdivision in which they are present. Borophagines were largely extinct in the Northwest by the end of the Clarendonian; this extinction appears to have allowed Caninae the opportunity to diversify elsewhere in North America (Tedford *et al.* 2009), though this diversification is not well documented in the Northwest due to a scarcity of Pliocene sediments. These patterns suggest that canid body mass may not be driven by climate, but by biotic interactions, particularly competition with other canids, leading to a pattern of taxonomic replacement and subsequent size increase.

Sciurids present a novel pattern: squirrel body mass does not change significantly throughout the course of the Arikareean-Hemphillian interval. This is true at all taxonomic levels from family to genus (*Protospermophilus*, for example, does not change significantly in size between the earliest Arikareean and the early Barstovian, a period of nearly 14 Ma). This pattern may not be typical of all squirrels: tree squirrels are known from the Northwest only from the Arikareean John Day fauna, chipmunks appear only in Clarendonian and Hemphillian faunas, and the giant marmot *Paenemarmota* appears only in the Thousand Creek fauna, accounting for the spike in squirrel body size observed in the Early Early Hemphillian. All other sciurids included in this study represent ground squirrels that were morphologically – and likely ecologically – analogous to the modern

Spermophilus (itself an important member of Late Miocene faunas in the region). Burrowing may serve to buffer ground squirrels and other fossorial rodents against a number of the proposed drivers of body size evolution (Hopkins 2007); these include not only temperature and other climatic variables, but also biotic interactions, in particular predation and competition. Further analyses of body size evolution in other burrowing taxa, particularly geomyids, will help establish whether similar trends are common to all fossorial mammals.

The lack of a correlation between climate and body size in the Oligo-Miocene is in sharp contrast to the patterns observed in extant mammals, including many canids and sciurids, which tend to show negative relationships with temperature and precipitation and positive relationships with seasonality (Ashton *et al.* 2000). It also contrasts with the results of previous studies of climate and mammal body size evolution, particularly Gingerich (2003) and Smith *et al*. (2010), both of which suggest a correlation between body mass and temperature. In both these cases, however, there are reasons to doubt that a causal relationship exists between the two variables. While the condylarth and perissodactyl genera examined by Gingerich do show a marked decrease in size coincident with the PETM, he suggests that the magnitude of body size change is far too large to be attributable solely to climate. While rising temperature may have played some role in the dwarfing of several mammal lineages, Gingerich suggests that other factors, particularly an increase in atmospheric CO_2 and a corresponding decrease in the nutritive value of plant leaves, are more likely responsible for driving body size evolution in Bighorn Basin mammals. The global-scale relationship between body mass and temperature posited by Smith *et al*. is suspect for several reasons. As discussed above, the scale of the study is too large to detect local or regional variation. Besides this, the authors used maximum body size within a taxon as a proxy for that taxon's mean body mass, a method based on a study by Trites and Pauly (1998) which showed the two to be correlated in marine mammals. Unfortunately, this is not necessarily the case in terrestrial mammals, which are subject to different constraints and selective pressures than aquatic taxa: not only does water provides more support than air, removing many constraints on body size, but large size is likely strongly selected for in most marine mammals because it allows more effective retention of heat (Riedman 1990). Further, as Smith *et al*. observe, there are many reasons to believe that the correlation they find between body mass and temperature does not imply causation. Global temperature is colinear with several other factors, including atmospheric oxygen concentration and land area. Further, Smith *et al*. did not consider other climatic variables in their analysis. As such, it is not possible to say whether temperature controls body size at a global scale or if body mass and temperature both respond to some third biotic or abiotic variable.

A correlation between climate and body size is not the only macroecological pattern observed in modern ecosystems that does not appear to have been present for large stretches of the Cenozoic: Rose *et al*. (2011), for instance, observed that there is no evidence for latitudinal richness gradients in North American Paleocene mammals. Any number of factors may account for such discrepancies between neontological and paleontological trends. Rose *et al*. suggest that the absence of strong Paleocene diversity gradients may be due to the faunal composition of the ecosystems studied (a large percentage of Paleocene mammals are members of extinct taxa with no modern analog and thus might not be expected to respond to environmental variables in the same way as extant mammals) or to a prolonged recovery from the end-Cretaceous mass extinction; because all three families studied here are represented by extant members and because the Arikareean-Hemphillian interval is not preceded by a major extinction event, neither of these factors can explain the absence of a relationship between Oligo-Miocene climate and body size. Instead, this may be due to the vastly different climatic regimes of the Oligo-Miocene and the Pleistocene and Holocene: recent climate is both aberrantly cool and volatile (Zachos *et al*. 2001) and what may appear in modern ecosystems to be strong relationships between climate ecological variables such as body size may not hold under the warmer conditions that have characterized most of the Cenozoic.

The implication of this study, that of Rose *et al*. (2011), and others like them that modern ecosystems are not necessarily keys to those of the past has important ramifications, chief among them that the present may also not be the key to the future. As anthropogenic global warming continues, so too will widespread environmental change. Well-calibrated ecological models are crucial to predicting and mitigating the effects of this change. Ecology has primarily used modern ecosystems and organisms as the basis for these models, but as climate change ushers in conditions with no historical precedent, neontologically-based models may begin to lose some of their predictive power. Augmenting environmental models with paleoecological data allows biotic responses to instances of large-magnitude climate change to be included and in so doing can enhance predictive power. Paleoecology also allows ecological questions to be addressed in a novel manner: instead of simply tracing biotic variables along a transect, transects from several time slices can be analyzed, allowing the study of how ecological gradients change through time, a method that is very applicable to the study of body size.

CHAPTER IV

LATITUDINAL BODY MASS TRENDS IN OLIGO-MIOCENE MAMMALS

Introduction

As the study of the relationship between organisms and their environment, ecology has historically focused on tracing biotic clines and on determining which factors shape them. These clines have been observed along a number of ecological gradients: two of ecology's foundational studies analyzed trends along elevational (Humboldt & Bonpland 1807) and latitudinal transects (Bergmann 1847), and modern researchers have traced patterns along climatic (e.g. Bradshaw 2010), water depth (e.g. Smith & Brown 2002), chemical (e.g. Hollister *et al*. 2010), and other gradients. Such research lays the foundation for the formulation of ecological models: by observing how organisms respond to a wide range of environmental conditions in modern ecosystems, it is possible to predict how the same organisms will respond to environmental changes in the future. These models are critically important to anticipating and mitigating the effects of anthropogenic climate change, but in some cases lack predictive power. This is partially because of the complexity of ecological interactions, in which several factors may influence biotic variables. It is also due in part to the complexity of the ecosystems themselves, in which many biotic and abiotic variables influence and are influenced by one another, making it difficult to tease out which variables are most important in shaping biotic patterns (Bateaux *et al*. 2006). Finally, models of future responses to environmental change based on neontological research are, of necessity, based on biotic variability across environmental regimes for which there is a historical precedent. Even the most conservative estimates of future warming indicate a rapidly increasing divergence from the climatic conditions that have characterized the Holocene (IPCC 2007), meaning that any prediction of biotic responses to this change requires extrapolating well beyond the range of modern data.

These last two concerns can be addressed by not only examining biotic clines within modern ecosystems, but by using the fossil and paleoenvironmental records to trace chronoclines, following ecological change through time. By applying a four-dimensional perspective to ecology, biotic responses to environmental conditions that do not exist in modern ecosystems can be observed and potential causal factors that are currently tightly tied to one another can be teased apart as they vary through time. This approach has historically played a small part in our understanding of ecological drivers of biological trends, in large part because of the perceived incompleteness of the fossil record and inaccuracy of paleoenvironmental reconstructions. However, many taxa are represented by very large fossil samples, and many regions have been the subject of rigorous paleoecological study, allowing robust reconstructions of trends along chronological transects and, at least in certain cases, the identification of causal factors. A great deal of paleontological research along these lines has focused on Cenozoic fossil mammals of North America, which are represented by an extremely rich fossil record that has been extensively collected for well over a century. These studies have, for the most part, tracked either mammal diversity (Alroy *et al*. 2000, Lillegraven 1972, Prothero 2004) or body size (Chapter 2 of this dissertation, Alroy 1998, Gingerich 2003, Koch 1986, Smith *et al*. 2010) through time. Others have examined the same variables along geographic transects at different intervals through time (Rose *et al*. 2011).

Chronocline analysis is especially well suited to address one of the longest-standing ecological questions: what drives mammal body size evolution? This question was first raised by Bergmann (1847), who observed that latitudinal body size gradients were visible within most mammal taxa at several taxonomic levels, with larger taxa or individuals tending to live towards the poles and smaller taxa or individuals living towards the equator. However, trying to tie body size to any other biotic or climatic variable has proven difficult. Bergmann himself suggested that the gradients he observed were a product of temperature, as large animals are better able to retain heat due to their small surface area to volume ratio, while smaller animals are more effective at shedding it. Subsequent studies have confirmed the patterns observed by Bergmann, finding body size gradients within most mammal taxa (Ashton *et al*. 2000, Blackburn & Hawkins 2004, Meiri & Dayan 2003, Rodríguez *et al.* 2008). While some authors have supported Bergmann's Rule *sensu stricto*, others have suggested that other ecological variables play a more direct role than temperature in driving body size evolution. Some of the proposed mechanisms posit biotic drivers. Primary productivity may limit the size to which herbivores can grow (Rosenzweig 1968), while large prey animals may select for large predators (Erlinge 1987). Size trends in island taxa suggests that competition may play an important role in shaping body mass patterns, but the effects of competition appear to vary between size classes (Damuth 1993), while predation pressure may select for larger prey taxa (Korpimäki & Norrdahl 1989). Besides temperature, two other climatic variables have been posited to play a major role in body size evolution: precipitation (large animals have a greater capacity for storing water and will be selected for in arid climates; James 1970) and seasonality (large animals have a greater capacity for fat reserves and will be selected for in seasonal climates; Millar & Hickling 1990).

Several paleontological studies have tested Bergmann's Rule, either explicitly or tangentially. These studies have ranged from local to global in scope and have reached divergent conclusions. Gingerich (2003) examined condylarth and perissodactyl body mass trends across the Paleocene-Eocene Boundary in Wyoming's Bighorn Basin, finding that all the taxa in question showed body mass spikes during the Paleocene-Eocene Thermal Maximum. However, Gingerich notes that the magnitude of these increases was too great to be explained solely by elevated temperatures, instead suggesting that dwarfing in Bighorn Basin mammals was due to a decrease in the nutritional value of plants, itself driven by the same rise in CO_2 levels that drove an increase in global temperature during the PETM. The second chapter of this dissertation details the results of study of body mass in three families of Oligo-Miocene mammals in the Northwest United States. No evidence was found of a causal relationship between any climatic variable and body mass; instead, different body mass profiles were observed within each family, suggesting that, for most of the Cenozoic, climate alone had little effect on body size evolution, and that the factors that do shape body mass trends are complex and vary between taxa. A correlation between body mass and mean annual temperature was observed in Cenozoic mammals at the global scale by Smith *et al.* (2010), seemingly supporting Bergmann's Rule *sensu stricto*. However, this study was based on maximum body size within taxa, which is not necessarily a reliable proxy for mean body mass within terrestrial taxa, and the authors themselves noted that there was insufficient evidence to determine whether the observed correlation between size and temperature was evidence of a causal relationship.

All of these studies have focused on body size change through time within a region, though the size of those regions has varied from individual basins to the entire planet. Conspicuously lacking from the paleontological study of mammalian body size evolution are analyses of geographic trends through time. In order to perform just such an analysis, we have reconstructed body size trends along the West Coast of North America, both among Oligo-Miocene equids, canids, and sciurids and among modern analogs for each family. These data are used to test the assertion of Bergmann (1847) and Smith *et al.* (2010) that body size in modern and Cenozoic mammals is driven by temperature. Taking Bergmann's Rule *sensu stricto* as a working hypothesis, three predictions can be made. First, body size should be positively correlated with latitude and negatively correlated with mean annual temperature during any given interval, as environments closer to the poles are always expected to be cooler than those near the equator. Second, because modern climate is considerably colder than has been the case during earlier intervals of the Cenozoic (Zachos *et al.* 2001), Oligo-Miocene lapse rates should be correspondingly lower and climatic gradients should be less steep, leading to weaker body mass clines in fossil taxa relative to extant ones. Third, as climatic gradients vary through time, the steepness of body mass gradients should vary, with steeper slopes during cooler intervals with high lapse rates and shallower slopes during warm intervals with low lapse rates.

Methods

The first hypothesis was tested by reconstructing body size trends along a transect running along the West Coast of North America from Washington to Oaxaca (Figure 12). Specimens from sites dating to the Arikareean-Hemphillian (Oligocene-Miocene, 30-5 Ma; Tedford *et al*. 2004) North American Land Mammal Ages (NALMAs) were included. This interval and region were chosen because of the remarkably rich fossil record (Carrasco *et al*. 2005). The West Coast of the United States (encompassing, for the purposes of this study, the states of Washington, Oregon, Nevada, and California) has an extensively sampled fossil record that has been collected for well over a century; while Mexican faunas have been the subject of less study historically, recent research has uncovered several diverse faunas, particularly from the states of Chihuahua, Guanajuato, and Oaxaca. Besides being extremely well sampled, the Arikareean-Hemphillian interval encompasses several important climatic events (Zachos *et al*. 2001), making it an ideal natural laboratory in which to examine the influence of temperature on biotic variables. The Late Oligocene is characterized by relatively cool temperatures, the onset of which was concurrent with the beginning of continental glaciation in Antarctica. The Early Miocene was characterized by markedly warmer temperatures, which culminated in the Mid-Miocene Climatic Optimum (MMCO; 16-14 Ma), a brief but significant warming spike representing the warmest period in Earth history since the Eocene. Climate cooled steadily in the Late Miocene, approaching the cold global temperatures seen today by 5 Ma.

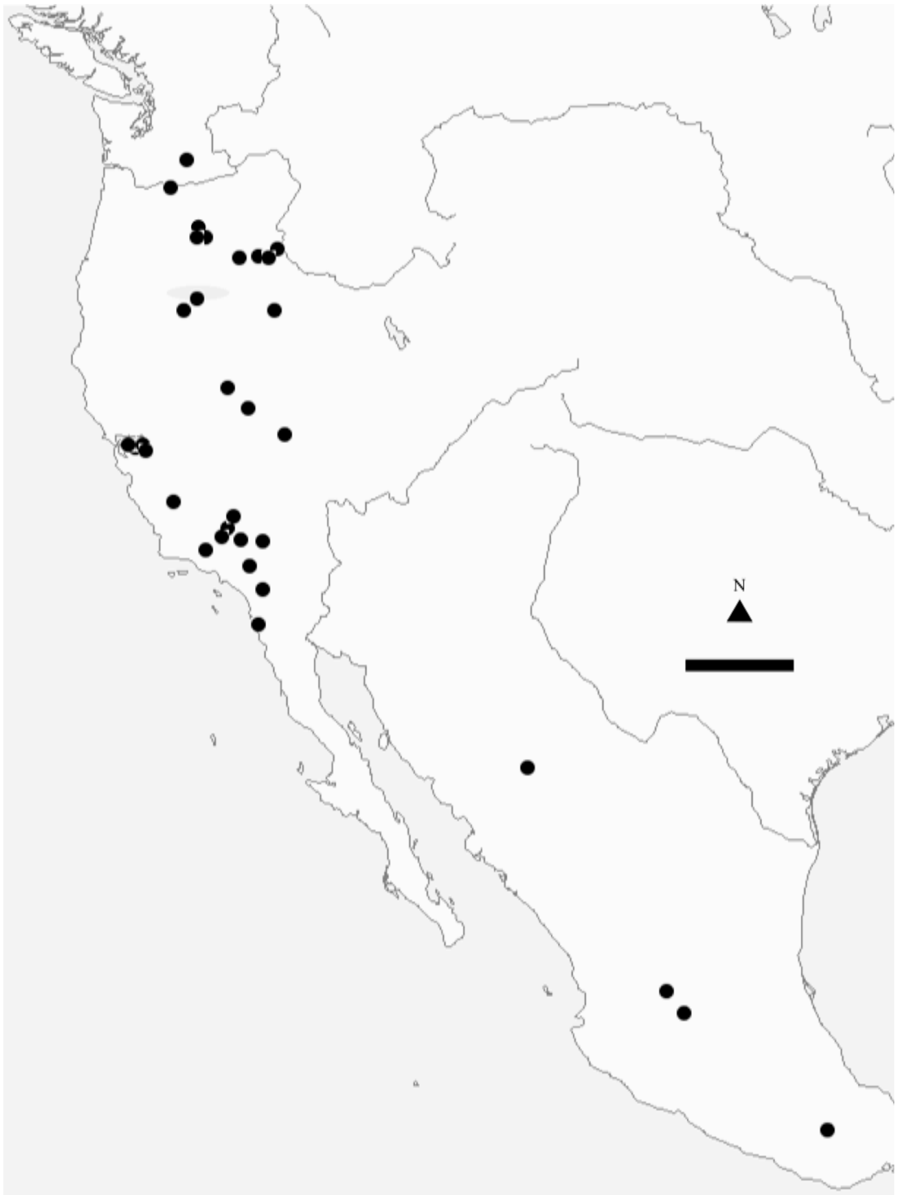

Figure 12. Map of study area. Circles represent formation included in this study. Scale bar represents 500 km.

The huge size of the Oligo-Miocene fossil record in North America makes an analysis of body size evolution in all mammals impractical, so this study focuses on trends within three representative families: equids, canids, and sciurids. Each family is distinct from the other two in its body size, diet, and ecology, and each is well represented in the fossil record (Carrasco *et al*. 2005). Besides being common, equids and canids have historically been the focus of a great deal of research, and this extensive study has led to the construction of robust and well-resolved phylogenies for both (Mac Fadden 1992, Tedford *et al*. 2009, Wang 1994, Wang *et al*. 1999). Sciurids, like many small mammals, have been the subject of less study, but are among the most common rodent families in the Oligo-Miocene. Crucially for the aims of this project, robust approximations of body mass exist for each family. For canids, body mass is approximated using the length of the first lower molar (Van Valkenburgh 1990), while sciurid body mass is strongly correlated with lower tooth row length (Hopkins 2008). Several dental proxies for mass exist for equids, including the lengths of all lower cheek teeth and the second upper molar (Janis 1990). The majority of the dental measurements used in this study were obtained from specimens in museum collections, though these were supplemented by some previously published measurements for faunas that were underrepresented in the collections visited. These collections were the American Museum of Natural History, Idaho Museum of Natural History, John Day Fossil Beds National Monument, Natural History Museum of Los Angeles County, Raymond Alf Museum, San Bernardino County Museum, Sierra College Museum of Natural History, San Diego Natural History Museum, South Dakota School of Mines & Technology, Universidad Nacional Autónoma de Mexico, University of California Museum of

Paleontology, University of Oregon Condon Fossil Collection, and University of Washington Burke Museum.

Body mass data for fossil taxa were analyzed within genera. Most studies of body size evolution in extant animals have focused on trends as the species level (Ashton *et al.* 2000), but a higher taxonomic level was used in this study for two reasons. Bergmann's Rule, as it was originally formulated, was meant to explain genus-level trends. Bergmann (1847) found the strongest body size gradients within genera, with large species towards the poles and small species towards the equator. As such, any test of Bergmann's Rule *sensu stricto* should be conducted at the generic level. The Oligo-Miocene fossil record also makes species-level analyses impractical. While the Arikareean-Hemphillian record is outstanding in its quality, it is not complete, and the lower the taxonomic level, the fewer specimens are available. Several genera are represented by sufficient numbers of individuals to make robust analyses possible, but few species are present in large enough numbers or over a large enough range to make them suitable subjects for body mass research. Besides this, few groups of Oligo-Miocene mammals have been the subject of intensive, large-scale taxonomic studies (though canids are an exception to this rule; Tedford *et al.* 2009, Wang 1994, Wang *et al.* 1999), and as such the diversity of named species may not reflect the taxon's true species diversity. Only in the case of sciurids and the equid genus *Merychippus* was body size examined at other taxonomic levels. Squirrels, despite being common, are only rarely identified below family level in collections. Because of the lack of positively identified lower taxa, sciurids must be studied at the family level. However, the vast majority of squirrels included here are morphologically similar, and likely behaviorally analogous, to the modern ground squirrel *Spermophilus*, so even at the family level the sciurids included here are anatomically and ecologically coherent. *Merychippus* is a paraphyletic genus that includes species of basal equines, hipparionins, and equines (MacFadden 1992). In the interest of including only monophyletic taxa, equin and hipparionin *Merychippus* were considered as two separate genera; only the latter was present along a large enough portion of the transect to be included here.

Whether or not body size gradients were present at different intervals during the Oligo-Miocene was tested by regressing body mass against temperature during different NALMA subdivisions (Tedford *et al.* 2004). Biostratigraphic units were used instead of million-year intervals due to the imprecision of dating for many West Coast sites, the vast majority of which are dated using relative rather than absolute methods (Carrasco *et al.* 2005). For all NALMA subdivisions for which data were available, body mass was regressed against latitude, a proxy for temperature during intervals in which no paleoclimatic estimates exist. However, extensive paleopedological research in Oregon allows climate for most NALMA intervals to be reconstructed there (Retallack 2007), and Early Barstovian floras in central Nevada and California's San Joaquin Valley have been used to estimate temperature in those regions (Yang *et al.* 2011; Table 7). This allows body mass to be compared directly to temperature in Early Barstovian genera present in Oregon, Nevada, or the San Joaquin Valley. For both sets of regressions, slopes were compared to a flat line to determine whether evidence exists for a directional relationship. Any significant departure from zero was taken indicate a significant relationship, but only slopes significantly more positive than zero were considered to support Bergmann's Rule.

Locality	Proxy	Region	MAT	Source
49 Camp	Paleobotanical	Central Nevada	9.4	Yang *et al*. 2011
Buffalo Canyon	Paleobotanical	Central Nevada	7.5	Yang et al. 2011
Eastgate	Paleobotanical	Central Nevada	9	Yang *et al*. 2011
Fingerrock	Paleobotanical	Central Nevada	8.6	Yang et al. 2011
Goldyke	Paleobotanical	Central Nevada	8.7	Yang *et al*. 2011
Mascall Ranch	Paleopedological	Columbia Plateau	14	Retallack 2007
Middlegate	Paleobotanical	Central Nevada	8.9	Yang et al. 2011
Temblor	Paleobotanical	San Joaquin Valley	17.3	Yang *et al*. 2011

Table 7. Sources of Early Barstovian paleoclimatic data and estimated mean annual temperatures (MAT) in degrees Celsius.

In order to test the second hypothesis, that body mass gradients in the Arikareean-Hemphillian interval should be weaker than those seen in modern taxa, body weights were collected for representative modern taxa from along the same transect (which was extended to include available data from British Columbian and Alaskan specimens). These data were regressed against both latitude and mean annual temperature for the site at which they were collected in order to create models to which the fossil data could be compared. This was preferable to using existing studies of Bergmann's Rule as the basis of models because it provided a higher degree of control, both analytically (both modern and fossil trends could be observed at the genus level, while most modern studies of body size focus on species-level trends) and geographically (both modern and fossil trends could be observed along an identical, constrained transect rather than extrapolating from a continent-wide patterns). Data were gathered from the online databases of the National Museum of Natural History, University of Alaska Museum of the North, University of California Museum of Vertebrate Zoology, University of New Mexico Museum of Southwest Biology, and University of Washington Burke Museum. The taxa chosen as comparisons for canids and sciurids were the canid *Canis* and the sciurid Spermophilus. No truly wild equids are currently extant in North America, so the cervid *Odocoileus* was used as a proxy. Deer are more common in most collections than other potentially analogous taxa, such as *Antilocapra* and *Bison*. While deer are browsers and thus ecologically not comparable to living horses, they are good analogs for Oligo-Miocene equids, many of which likely retained a much higher percentage of browse in their diet than modern taxa (Janis *et al*. 2000, MacFadden *et al*. 1999). The slopes obtained from these modern regressions were compared to those from fossil genera to determine whether or not significant differences were present. Bergmann's Rule was considered to be supported if slopes were less steeply positive in fossil genera than in their modern comparisons.

The third hypothesis, that the steepness of body size gradients should vary through time in relation to climate, was tested by comparing the slope of the relationship between body mass and latitude within a genus to all other fossil members of the same family. If a genus from a colder interval (e.g. Late Oligocene, Late Miocene) had a significantly more positive relationship with latitude than related genera from a warmer interval (e.g. the MMCO), Bergmann's Rule was considered to be supported.

Results

The first series of tests run were to determine whether or not latitudinal or climatic body size gradients were present in Oligo-Miocene mammals. Of the 19 genera for which latitudinal trends could be analyzed, only five were found to have a slope that differed significantly ($p < 0.05$) from a flat line. Among equids, Early Barstovian hipparionin *Merychippus* ($p=0.02$) and Late Late Hemphillian *Dinohippus* ($p=0.0006$) both show a significant positive relationship with latitude (Figure 13, Table 8). A similar positive correlation was found in the Late Barstovian canid *Paracynarctus* ($p=0.01$; Figure 14, Table 8). No sciurids show a significant relationship with latitude (Figure 15, Table 8). In total, five Early Barstovian genera were present in sufficient numbers from localities for which climate could be reconstructed to directly analyze the relationship between temperature and body mass. In only one of these taxa (hipparionin *Merychippus*) was a significant ($p=0.0007$) negative correlation present (Figures 16 & 17, Table 9)

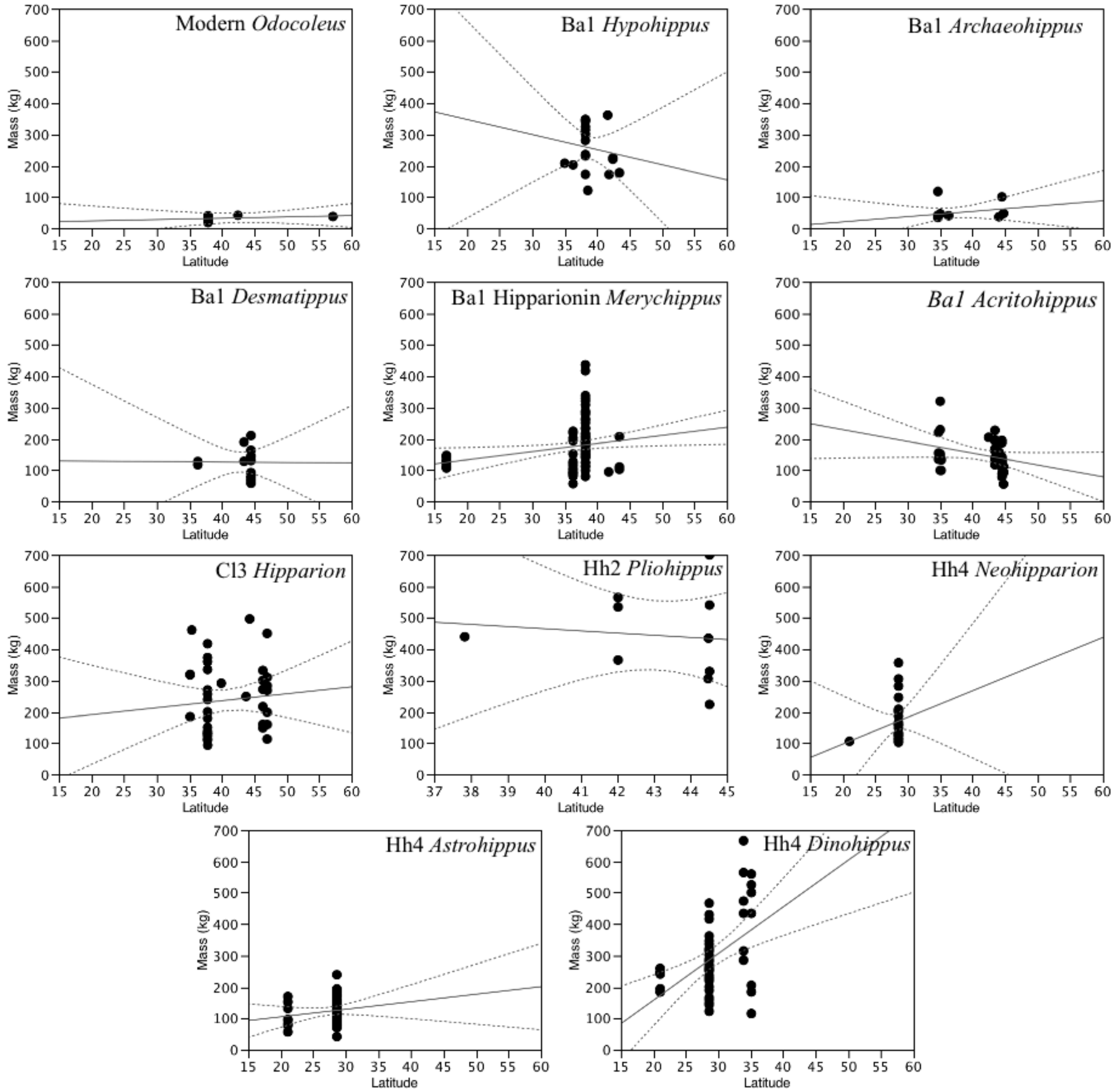

Figure 13. Latitudinal body mass gradients in modern *Odocoileus* and fossil equids. Land mammal age subdivisions are denoted by abbreviations (Ba=Barstovian, Cl=Clarendonian, Hh=Hemphillian). Solid line represents slope of regression; dotted lines indicate 95% confidence intervals.

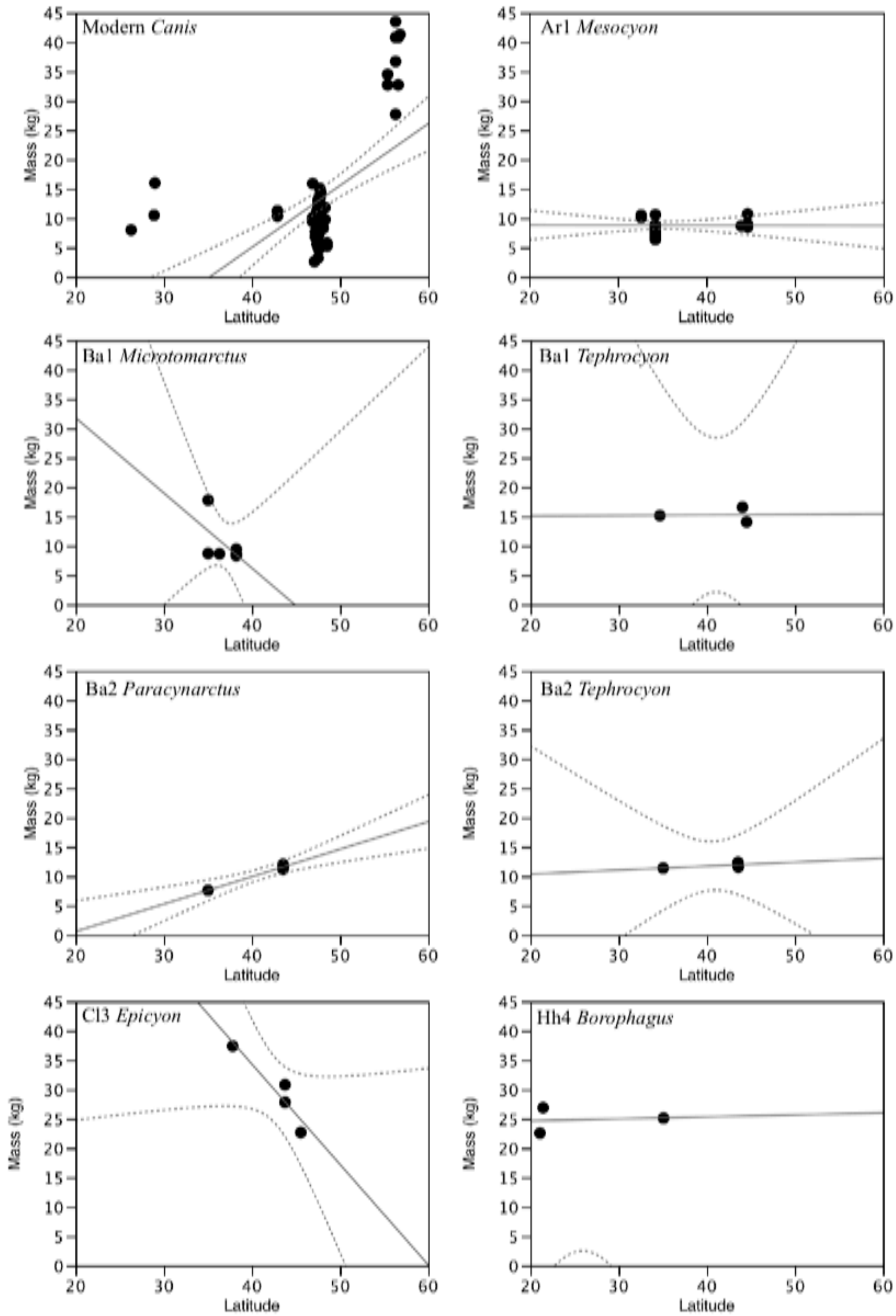

Figure 14. Latitudinal body mass gradients in modern and fossil canids. Land mammal age subdivisions are denoted by abbreviations (Ar=Arikareean, Ba=Barstovian, Cl=Clarendonian, Hh=Hemphillian). Solid line represents slope of regression; dotted lines indicate 95% confidence intervals.

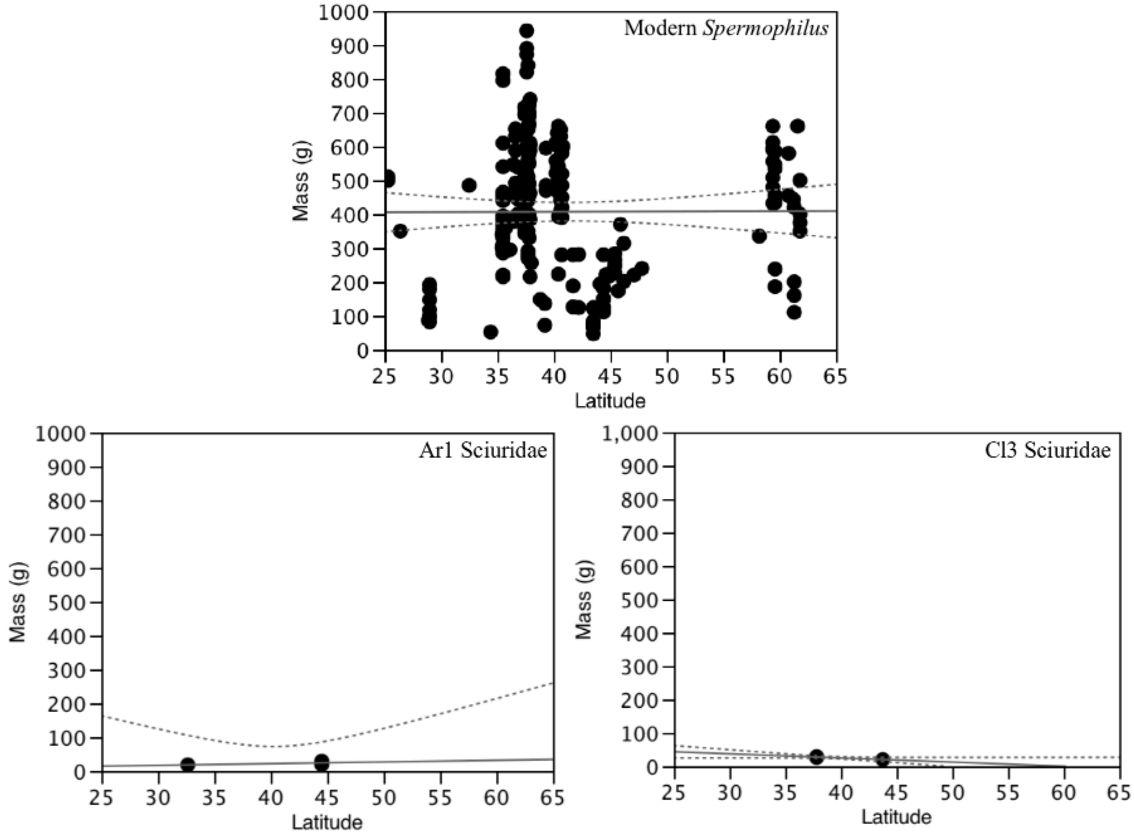

Figure 15. Latitudinal body mass gradients in modern and fossil sciurids. Land mammal age subdivisions are denoted by abbreviations (Ar=Arikareean, Cl=Clarendonian). Solid line represents slope of regression; dotted lines indicate 95% confidence intervals.

	Age	n	R^2	Slope	CI	Diff 0	Diff Modern	Diff Genera
Odocoileus	Modern	5	0.14	0.40	1.18	No	NA	NA
Hypohippus	Ba1	19	0.02	-4.80	15.29	No	No	No
Archaeohippus	Ba1	13	0.07	1.70	3.72	No	No	*Dinohippus*(-)
Desmatippus	Ba1	12	0.00	-0.10	9.21	No	No	No
Hipparionin *Merychippus*	Ba1	102	0.05	2.60	2.16	Yes(+)	No	*Acritohippus*(+) *Dinohippus*(-)
Acritohippus	Ba1	36	0.09	-3.80	3.92	No	No	*Merychippus*(-) *Dinohippus*(-)
Hipparion	Cl3	43	0.01	2.20	7.25	No	No	No
Pliohippus	Hh2	10	0.01	-7.00	45.08	No	No	No
Neohipparion	Hh4	27	0.04	8.50	17.44	No	No	No
Astrohippus	Hh4	49	0.03	2.40	4.12	No	No	*Dinohippus*(-)
Dinohippus	Hh4	56	0.20	14.90	8.04	Yes(+)	Yes(+)	*Archaeohippus*(+) *Merychippus*(+) *Acritohippus*(+) *Astrohippus*(+)
Canis	Modern	77	0.32	1.05	0.39	Yes(+)	NA	NA
Mesocyon	Ar1	25	0.00	-0.00	0.14	No	Yes(-)	*Paracynarctus*(-) *Epicyon*(+)
Microtomarctus	Ba1	6	0.30	-1.30	1.96	No	No	No
Tephrocyon	Ba1	3	0.00	0.01	0.39	No	Yes(-)	*Epicyon*(+)
Paracynarctus	Ba2	4	0.97	0.50	0.12	Yes(+)	Yes(-)	*Mesocyon*(+) *Epicyon*(+)
Tephrocyon	Ba2	3	0.41	0.07	0.16	No	Yes(-)	*Epicyon*(+)
Epicyon	Cl3	4	0.88	-1.70	0.78	No	Yes(-)	*Mesocyon*(-) Ba1*Tephrocyon*(-) *Paracynarctus*(-) Ba2*Tephrocyon*(-) *Borophagus*(-)
Borophagus	Hh4	3	0.02	0.03	0.59	No	Yes(-)	*Epicyon*(+)
Spermophilus	Modern	210	0.00	0.09	3.14	No	NA	NA
Sciuridae	Ar1	3	0.33	0.50	1.37	No	No	No
Sciuridae	Cl3	4	0.90	-1.20	0.59	No	No	No

Table 8. Comparison of latitude and body mass regressions between fossil and modern genera. Slope, sample size, correlation coefficient, and 95% confidence intervals for the slope are indicated in each column. ‘Diff Modern’ and ‘Diff 0’ indicate whether the slope of a line differs significantly from that seen in the comparative modern genus or from zero. ‘Diff Genera’ indicates whether a genus has a significantly more positive or negative relationship with latitude than other fossil taxa. Significantly more positive or negative slopes are indicated by a (+) or (-).

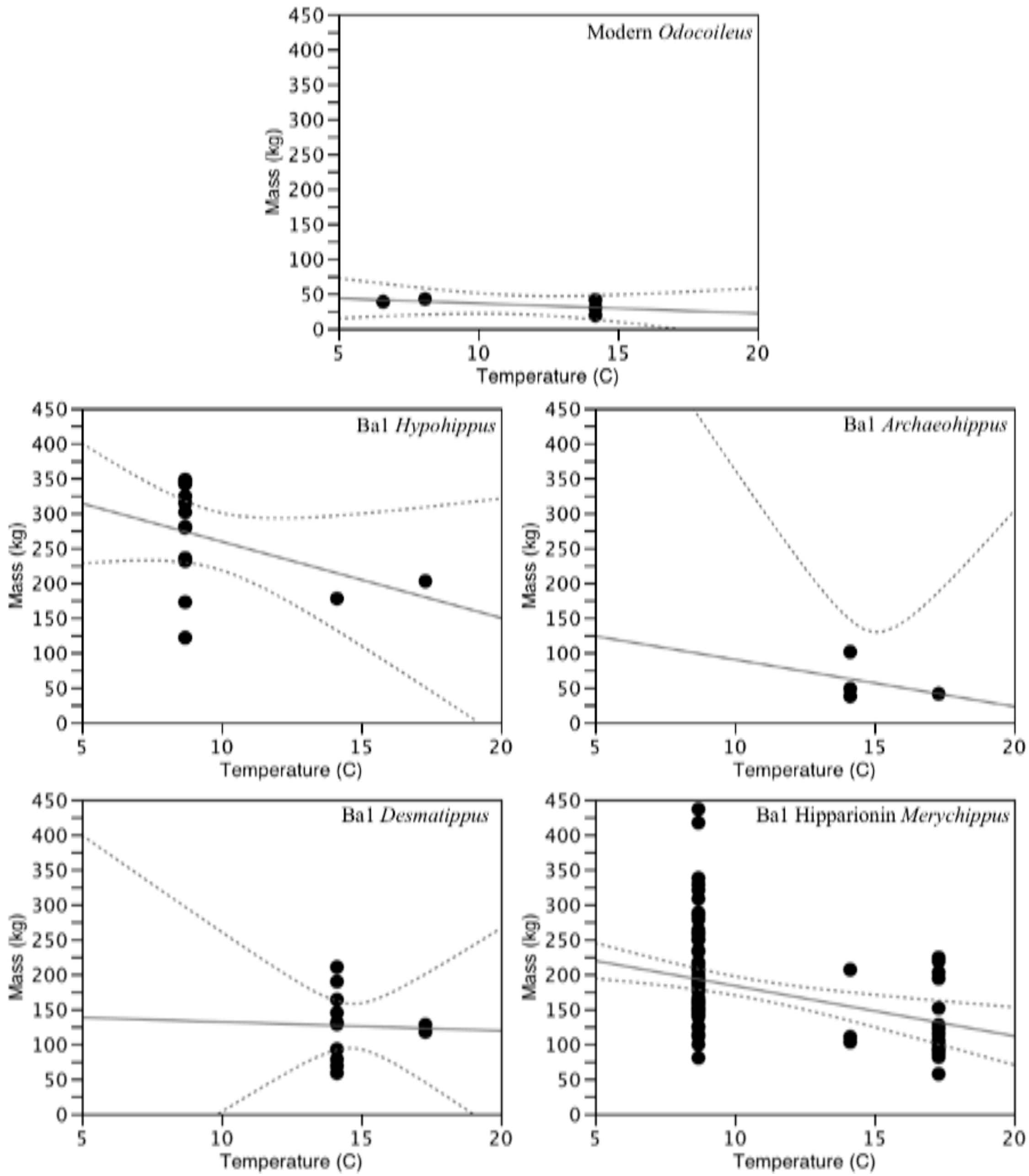

Figure 16. Climatic body size gradients in modern *Odocoileus* and Early Barstovian equids. Solid line represents slope of regression; dotted lines indicate 95% confidence intervals.

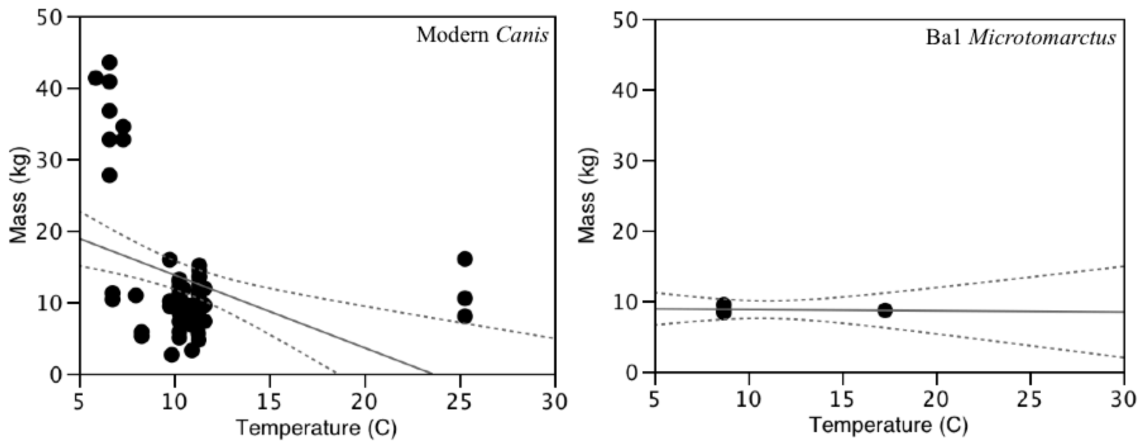

Figure 17. Climatic body size gradients in modern and Early Barstovian canids. Solid line represents slope of regression; dotted lines indicate 95% confidence intervals.

	n	R^2	Slope	CI	Diff 0	Diff Modern
Odocoileus	5	0.31	-1.4	2.35	No	NA
Hypohippus	14	0.15	-10.9	14.50	No	No
Archaeohippus	4	0.13	-6.7	24.30	No	No
Desmatippus	12	0.0011	-1.3	23.52	No	No
Hipparionin *Merychippus*	93	0.12	-7.2	3.92	Yes(-)	No
Canis	77	0.14	-1.0	0.59	Yes(-)	NA
Microtomarctus	4	0.026	-0.02	0.16	No	Yes(+)
Spermophilus	210	0.00055	-0.7	4.17	No	NA

Table 9. Comparison of temperature and body mass regressions between Early Barstovian and modern genera. Slope and 95% confidence intervals for the slope are indicated in each column. 'Diff Modern' and 'Diff 0' indicate whether the slope of a line differs significantly from that seen in the comparative modern genus or from zero. Significantly more positive or negative slopes are indicated by a (+) or (-).

The second series of tests established modern models for body size gradients, against which fossil data were compared to determine whether the steepness of these gradients was different during earlier intervals of the Cenozoic. Of the three modern genera analyzed, only *Canis* was found to show a significant ($p<0.0001$) positive correlation with latitude and a negative correlation ($p=0.0009$) with temperature (Figures 14 & 17, Tables 8 & 9); no evidence for latitudinal or climatic gradients was found in either *Odocoileus* (Figures 13 & 16, Tables 8 & 9) or *Spermophilus* (Figure 15, Tables 8 & 9). The only equid to show a significantly more positive relationship with latitude than modern *Odocoileus* was Late Late Hemphillian *Dinohippus* (Figure 14, Table 8). Sciurids, too, did not depart significantly from the pattern observed in modern *Spermophilus* (Figure 15, Table 8). Conversely, all but one canid genus (Early Barstovian *Microtomarctus*) was found to show a pattern statistically similar to modern *Canis*; all other canids had a significantly more negative slope (Figure 14, Table 8). *Microtomarctus*, the only Early Barstovian canid in which a comparison of body size to temperature was possible, also shows a significantly more positive relationship than does *Canis* (Figure 17, Table 9). None of the four equids analyzed from this interval shows a significant departure from the trend seen in *Odocoileus* (Figure 16, Table 9).

The third series of tests compared fossil genera from the same family in order to determine if the slope of latitudinal body size gradients changed through time. The Late Late Hemphillian equid *Dinohippus* shows a significantly more positive relationship with latitude than does the coeval *Astrohippus* and Early Barstovian *Archaeohippus*, hipparionin *Merychippus*, and *Acritohippus* (Figure 13, Table 8). *Acritohippus* also shows a significantly less positive relationship with latitude than does hipparionin

Merychippus of the same age. Late Clarendonian *Epicyon* has a strongly negative slope that is significantly steeper than that seen in any other canid included in this study with the exception of Early Barstovian *Microtomarctus* (Figure 14, Table 8). The only other significant difference between slopes among canids is between the positive trend visible in Late Barstovian *Paracynarctus* specimens and the neutral trend visible in Early Early Arikareean *Mesocyon*. *Tephrocyon*, the only genus in this study present in more than one temporal bin, does not show any significant difference in slope between the Early and Late Barstovian. Sciurids are present in both the Early Early Arikareean and the Late Clarendonian, and the slope of their body mass gradient does not change significantly between these two intervals.

Discussion

Hypothesis Tests

The findings of this study do not support Bergmann's Rule either in modern or in prehistoric ecosystems. The first prediction derived from Bergmann's (1847) model predicts that, in any given interval, body size should be positively correlated with latitude and negatively correlated with temperature. With the exception of only a small number of taxa, this is not the case in this study. The overwhelming majority of fossil taxa (16 out of 19) show no evidence of directional latitudinal trends in body mass. Likewise, only one of the five Early Barstovian taxa compared directly to temperature shows a significant relationship between body mass and climate. While the slope of such relationships might be expected to vary with time, their near absence within the genera analyzed in this study suggests that they are the exception rather than the rule, falsifying the first prediction tested here.

The second prediction derived from Bergmann's Rule – that taxa from the Oligo-Miocene should show shallower latitudinal and climatic temperature gradients – is supported more strongly in some taxa than in others. Only one equid genus has a body mass-latitude slope that differs significantly from that of *Odocoileus*, and neither of the fossil sciurid samples shows a significant difference from *Spermophilus*, though it is worth noting that there is no evidence for a latitudinal or climatic body mass gradient in either modern genus. A significant latitudinal gradient in keeping with the predictions of Bergmann's Rule is present within *Canis*, however, and its slope is significantly steeper than that seen in all fossil canids except *Microtomarctus* (which does, however, show a more positive relationship with temperature). If these data are taken at face value, then, the prediction that body size gradients were weaker during much of the Cenozoic than they are today is supported in canids, though it lacks support among equids and sciurids.

Bergmann's Rule also fails in its prediction that stronger gradients should be present within genera during colder intervals. Some genera do show relationships with climate that are stronger than those seen in related genera, and some of these, most notably Late Late Hemphillian *Dinohippus*, are present during particularly cool intervals. However, such instances are by no means the rule; while *Dinohippus* has a very strong latitudinal gradient relative to other equids, including those from warmer intervals, the closely related *Astrohippus* and the more distantly related *Neohipparion* from the same time and same sites do not. In some cases, the observed patterns directly contradict the predictions made by Bergmann's Rule: strong gradients relative to other taxa are present among hipparionin *Merychippus* specimens during the Barstovian MMCO, the warmest interval of this study (Zachos *et al*. 2001), when gradients are expected to be relatively weak. Likewise, Barstovian *Paracynarctus* specimens show a stronger relationship with latitude than do *Mesocyon* specimens from the Arikareean, one of the coldest intervals of the Oligo-Miocene. These patterns demonstrate that the slope of latitudinal body size gradients does not vary with global temperature, refuting the third prediction tested here.

Potential Biases in the Fossil Record

The results obtained in this study have thus far been considered to represent genuine ecological signals, but as is always the case in paleontology, taphonomic and analytical biases must be considered. One potential confounding factor in this study is the scarcity of paleoclimatic data from the southern end of the transect (particularly California and Mexico). Floras from which paleoclimate can be reconstructed are scarce south of Nevada, and paleoclimatic reconstructions based on paleopedological or isotopic proxies are nonexistent, even for extremely productive and well-studied localities and faunas (the most striking example being the Barstow Fauna of Southern California, a fauna that has been so well studied that it has lent its name to a NALMA but has never been the subject of a rigorous, quantitative paleoclimatic analysis). This dearth of climatic data was the rationale for using latitude as a proxy for temperature during most intervals. Temperature and latitude are tightly correlated ($R2=0.67$, $p<0.0001$) in modern ecosystems (Figure 18), but the relationship is not perfect; it is reasonable to expect that temperature might vary between sites at similar latitudes but at differing distances from the coast. This is particularly a concern in California and Nevada, where sites from the Great Basin and Mojave Desert sit at the same latitude as sites from the San Francisco Bay Area and the Los Angeles Basin. Without more paleoclimatic work, it is impossible to quantitatively assess the magnitude of the difference in temperature between these regions, but it is likely that, just as today, coastal temperatures were mediated by the ocean and were likely lower than those of inland sites. However, due to the richness of the fossil record in the region, it is possible to test whether or not such differences affected mammal body size. Ten genera (nine horses and one canid) have been found at both coastal and inland sites during the same interval, and in only one case (Middle Clarendonian *Pliohippus*) is there a significant difference between body mass between the two regions (Table 10). As such, it seems unlikely that small-scale climatic differences are obscuring large-scale latitudinal patterns and that latitude can be used as a proxy for temperature when no direct measurement is available.

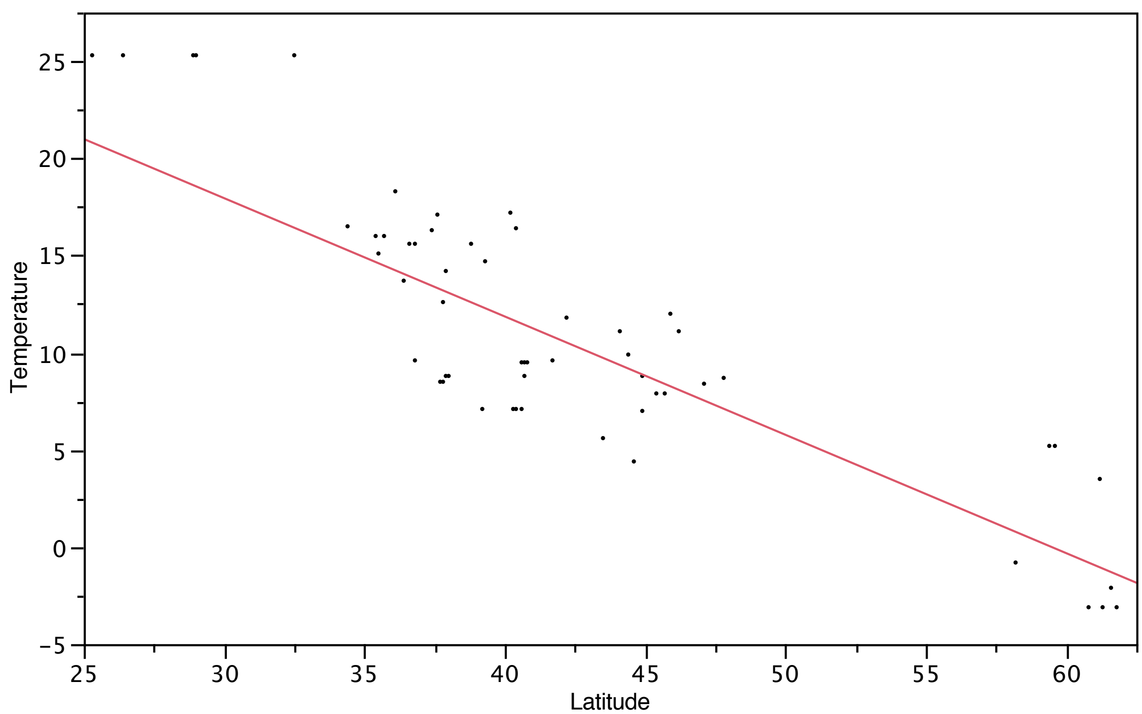

Figure 18. Correlation between latitude and temperature along the modern West Coast of North America. R^2=0.67, $p<0.0001$.

		Bay Area	San Joaquin Valley	Transverse Ranges	Western Nevada	Mojave Desert
Ba1 *Microtomarctus*	**Mass**		15.30		15.44	19.06
	CI		NA		0.62	7.25
Ba1 *Hypohippus*	**Mass**		202.22		274.26	207.42
	CI		NA		40.70	NA
Ba1 *Archaeohippus*	**Mass**		40.78	46.26		46.90
	CI		NA	20.17		NA
Ba1 *Scaphohippus*	**Mass**			148.70		174.85
	CI			24.71		29.61
Ba1 *Acritohippus*	**Mass**			169.73		168.04
	CI			50.60		58.98
Cl2 *Hipparion*	**Mass**	226.08				319.81
	CI	107.57				NA
Cl2 *Pliohippus*	**Mass**	409.23		196.82	234.26	336.29
	CI	190.89		36.53	NA	88.21
Cl3 *Hipparion*	**Mass**	202.86	273.69		290.95	461.21
	CI	40.65	87.78			
Cl3 *Neohipparion*	**Mass**	126.46			476.10	
	CI	56.07			355.57	
Cl3 *Pliohippus*	**Mass**	395.37	492.17			404.70
	CI	136.50	61.75			NA

Table 10. Comparison of body mass data from coastal and inland sites. Mean mass (in kg) and 95% confidence intervals are shown for each genus. Bay Area, San Joaquin Valley, and Transverse Ranges biogeography regions are considered coastal; Western Nevada and Mojave Desert biogeographic regions are considered inland.

Another constant concern in paleontology is the quality of the fossil record. Not only are whole ecosystems rarely preserved, but an already incomplete record is often further biased by differential preservation, collection (Behrensmeyer *et al*. 2000), and description (Davis & Pyenson 2007), creating taphonomic noise that can obscure true biological signals if insufficiently large samples are considered. This is especially a concern for taxa – such as canids and other carnivores – that are well sampled and extensively studied, but are generally rare within ecosystems and for taxa – such as sciurids and other rodents – that are common within ecosystems but are either infrequently preserved or undercollected. Sample size is demonstrably driving at least one signal in this study: Late Clarendonian *Epicyon* shows a strong negative correlation with latitude, but this is almost certainly the result of an incomplete sample. Wang *et al*. (1999) note that two species of *Epicyon* are present at Late Clarendonian sites throughout North America: the giant *E. haydeni* and the smaller *E. saevus*. As discussed in the first chapter of this dissertation, both are present in the Juntura Formation of Oregon, but only *E. haydeni* is represented by dental material from the coeval Contra Costa Group of the San Francisco Bay Area. Were the sample size from this site larger, it would almost certainly include *E. saevus*, likely obscuring the seemingly strong latitudinal gradient. The small sample size of many other canid and sciurid taxa makes it possible, or even likely, that many the patterns observed here do not reflect biological trends. It is worth noting, however, that sample size cannot be invoked to explain every body size gradient – or lack thereof – in canids. *Mesocyon* is both extremely common and extremely well sampled in Arikareean faunas (Wang 1994), and is present in large numbers (n=25) in the latitudinally distant John Day and Otay Formations. While the Arikareean is one of the coldest intervals of the Oligo-Miocene, there is no evidence of a significant difference in *Mesocyon* size between southern California and Oregon. Likewise, sample size cannot explain most of the patterns observed in equids, which are both common and well sampled; even the most poorly sampled equid in the database (Late Early Hemphillian *Pliohippus*) has a sample size of 10, and *Merychippus* is represented by over 100 specimens. As such, significant results such as the positive correlations between body mass and latitude in *Merychippus* (n=102) and *Dinohippus* (n=56) are likely not taphonomic artifacts but can be interpreted as ecological trends. The same is true, though, for the patterns observed in other well-sampled taxa such as *Acritohippus* (n=36), *Hipparion* (n=43), and *Astrohippus* (n=49), in which no latitudinal gradient is visible. Taphonomic bias is also unlikely to affect these patterns too strongly, as in many cases, taxa sampled in similar numbers and from the same sites (e.g. *Dinohippus* and *Astrohippus*) show different patterns.

Such patterns further support the suggestion made in Chapter 2 of this dissertation that the same environmental conditions, both biotic and abiotic, may influence different taxa in different ways. This was shown to be true at the family level in Chapter 2, but the data presented here suggest that biotic patterns can vary considerably even between closely related genera; *Merychippus* and *Acritohippus*, for instance, are both *Merychippus*-grade equids, but while the former shows a strong latitudinal gradient, the latter does not. The same is true of *Dinohippus* and its close, but smaller, relative *Astrohippus*. Not only do body size patterns vary between coeval taxa, but they often vary between closely related taxa through time. The Late Miocene hipparionins *Hipparion* and *Neohipparion*, for example, are likely descended from the hipparionin merychippines of the mid-Miocene (MacFadden 1992), but whereas *Merychippus* shows latitudinal gradients, its probable descendants do not. Bergmann's "Rule," then, does not only apply to some taxa and not others, but does not apply to similar taxa at different points in time.

Modern Gradients

The most striking result of this study is the absence of latitudinal gradients among the modern genera examined. Despite a very large sample size, there is no evidence for either a positive or a negative relationship between body size and temperature or latitude in *Spermophilus*. A negative correlation with temperature and a positive correlation with latitude, both in keeping with Bergmann's Rule, are visible in *Odocoileus*, but the sample is insufficiently large to establish whether or not the trend is significant (while deer are common, they also often lack weight data in collections, as individuals tend to be large and difficult to measure accurately). Only within *Canis* are significant trends apparent. However, these patterns are likely a sampling artifact: specimens from the contiguous United States and southern Canada are almost exclusively coyotes (*C. latrans*), while specimens from northern Canada and southeast Alaska are almost all wolves (*C. lupus*). While neither of these species shows a significant relationship with temperature or latitude, wolves are larger than coyotes, and their presence at the north end of the transect accounts for the negative correlation with temperature and positive correlation with latitude. At first glance, this seems to support Bergmann's Rule *sensu stricto*, as it is a case of larger species within a genus occupying colder climates. However, it is unlikely that this is a truly natural signal, as wolves have been extirpated over large areas of the contiguous United States, and many of these extirpations took place before systematic specimen collecting had taken hold or at the hands of individuals with no scientific interest in preserving data about the animals they had killed. Were reliable data to exist for wolf populations along the southern end of the coastal transect, they would very likely obscure the trend currently visible in the data. In this case, all three modern genera included in this study would fail to conform to the predictions made by Bergmann's Rule. If the appearance of a latitudinal gradient in *Canis* is in fact a sampling artifact, the appearance of weak gradients in fossil taxa relative to the modern model would likely disappear, falsifying the second prediction tested in this study for all three families.

This finding also seemingly falsifies the many others that have shown latitudinal body size gradients or relationships with temperature in modern taxa (Ashton *et al*. 2000). This may be due in part to the level at which the studies were conducted: almost all modern research on body size evolution has focused on patterns within species. It may be that temperature and body mass interact at a very fine scale and that geographic trends become obscured at higher taxonomic levels. This would run counter to Bergmann's (1847) observation of body mass gradients within genera and would contradict his suggestion that the forces driving trends within genera should drive similar trends at all taxonomic levels. Another possibility is that the source of the data for these studies is influencing the patterns observed in them. Bergmann's research, and several landmark studies in the field since (e.g. Erlinge 1987, Korpimäki & Norrdahl 1989), focused on mammals in Europe. As is the case with wolves in North America, many large animals have long since been extirpated from the southern, temperate parts of Europe and, if they survive at all, are present only in the inaccessible regions of the continent. These regions tend to be cold and are, for the most part, located far to the north, and this alone could explain the appearance of latitudinal gradients and of a negative correlation between temperature and body size. Studies of Bergmann's Rule have, of course, been conducted in other areas as well, but the example of the wolves proves that even on relatively "wild" continents such as North America, extirpation and extinction can strongly influence body mass patterns.

The apparent lack of latitudinal body size gradients in the modern taxa examined here raises the question of whether a fossil test of Bergmann's Rule is even necessary; if the pattern doesn't exist in modern ecosystems, why should we expect it to have been present in the past? This question might especially be asked of studies like this one that delve back into deep time into ecosystems that are not analogous to those we see today. In fact, it is precisely because fossil and modern ecosystems are not entirely analogous that such studies are worthwhile. On a practical level, if there are concerns that a biotic pattern such as Bergmann's Rule is driven in part by human activity, these concerns can be addressed by examining ecosystems that predate the evolution or immigration of *Homo sapiens*. There are other, more fundamental ways, in which the study of body size evolution in fossil animals can and should influence our understanding of the same phenomenon in modern ecosystems. As discussed above, other ecological "rules," such as a correlation between latitude and diversity, do not apply during other intervals of the Cenozoic (Rose *et al*. 2011), and the only way to study these intervals is through the fossil record. Paleoecology can also supply a perspective on changing responses to ecological pressures within a taxon unavailable to neontologists. Patterns such as the shift from strong body size gradients in *Merychippus* to the absence of such gradients in later hipparionin species reveal variable responses to (or, alternatively, stasis in the face of) changing environmental drivers that could not be observed by studying only modern taxa and ecosystems. Understanding the degree of temporal variability in any ecological model is as critical to maximizing the predictive power of that model as understanding variability across a modern environmental gradient. In this context, the largely negative results of this study that suggest that Bergmann's Rule is not now, and has never been, a monolithic ecological "law" are as informative as a confirmation of Bergmann's (1847) hypothesis would have been. As the fossil record becomes increasingly well sampled and as paleoclimatic proxies become increasingly robust, paleoecology should continue to play a key role in our understanding of how the abiotic environment shapes evolutionary trends.

APPENDIX A

CHAPTER III DATA

Repository – Collection in which specimen is located

Specimen # - Identification number of specimen

Taxonomy (Family, Subfamily, Tribe, Sub tribe, Genus, Species) – Specimen taxon

Site – Name of site at which specimen was found

Site # - Identification number of site

Formation – Formation in which specimen was found

Age – NALMA subdivision to which the specimen can be dated

Source – Source of measurement

2LPL – 2nd lower premolar length

3LPL – 3rd lower premolar length

4LPL – 4th lower premolar length

1LML – 1st lower molar length

2LML – 2nd lower molar length

3LML – 3rd lower molar length

2UML – 2nd upper molar length

Repository Specimen #	AMNH 6860	AMNH 6863	AMNH 6879	AMNH 6881	AMNH 6885	AMNH 6896	AMNH 6897	AMNH 6902	AMNH 6904
Family	Canidae	Canidae	Canidae	Canidae	Canidae	Canidae	Canidae	Canidae	Canidae
Subfamily	Hesperocyoninae	Hesperocyoninae	Borophaginae	Borophaginae	Borophaginae	Borophaginae	Borophaginae	Hesperocyoninae	Hesperocyoninae
Tribe			Basal Borophaginae	Basal Borophaginae	Borophagini	Phlaocyonini	Phlaocyonini		
Subtribe					Basal Borophagini				
Genus	*Mesocyon*	*Paraenhydrocyon*	*Rhizocyon*	*Rhizocyon*	*Cormocyon*	*Phlaocyon*	*Phlaocyon*	*Enhydrocyon*	*Enhydrocyon*
Species	*coryphaeus*	*josephi*	*oregonensis*	*oregonensis*	*copei*	*latidens*	*latidens*	*stenocephalus*	*basilatus*
Site	The Cove	Camp Creek	Diceratherium Beds	Camp Creek	John Day Basin	Diceratherium Beds	Diceratherium Beds	The Cove	Haystack Valley
Site #									
Formation	John Day	John Day	John Day	John Day	John Day	John Day	John Day	John Day	John Day
Age	Ar1	Ar1	Ar1	Ar1	Ar1	Ar1	Ar1	Ar1	Ar2
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	15.68	14.95	9.85	10.18	11.09	8.63	8.04	20.67	23
2LML									
3LML									
2UML									

Repository Specimen #	AMNH 6907	IMNH 11959	IMNH 13856	IMNH 24584	IMNH 24632	IMNH 27930	IMNH 29087	IMNH 29088	IMNH 36312
Family	Canidae	Equidae	Equidae	Canidae	Canidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Borophaginae	Equinae	Equinae	Caninae	Borophaginae	Equinae	Equinae	Equinae	Equinae
Tribe	Phlaocyonini	Hipparionini	Equini	Vulpini	Borophagini	Equini	Equini	Equini	Equini
Subtribe					Borophagina				
Genus	*Phlaocyon*	*Cormohipparion*	*Pliohippus*	*Metalopex*	*Epicyon*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Merychippus*
Species	*latidens*	*plicoartus*	*spectans*	*merriami*	*haydeni*				
Site	John Day Basin	Sugar Creek	Little Jacks Creek / Wickahoney / Little Valley	Star Valley	Star Valley	Star Valley	Star Valley	Star Valley	Sheaville / Coal Mine Basin
Site #		676	1081	67001	67001	67001	67001	67001	82005
Formation	John Day	Chalk Butte	Chalk Butte	Chalk Butte	Chalk Butte	Chalk Butte	Chalk Butte	Chalk Butte	Sucker Creek
Age	Ar1	Hh1	Hh1	Hh2	Hh2	Hh2	Hh2	Hh2	Ba1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL			26.97						
3LPL							24.99		
4LPL									
1LML	8.5			14.62	38.63	29.3			17.98
2LML									
3LML		23.69						33.28	
2UML									

Repository Specimen #	JODA 333	JODA 771	JODA 791	JODA 1086	JODA 1243	JODA 1344	JODA 1345	JODA 2020	JODA 2021
Family	Canidae	Canidae	Canidae	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Hesperocyoninae	Caninae	Borophaginae	Anchitheriinae	Borophaginae	Anchitheriinae	Anchitheriinae	Equinae	Equinae
Tribe		Basal Caninae	Phlaocyonini		Phlaocyonini				
Subtribe									
Genus	*Mesocyon*	*Leptocyon*	*Phlaocyon*	*Miohippus*	*Phlaocyon*	*Parahippus*	*Parahippus*	*Merychippus*	*Merychippus*
Species	*coryphaeus*	*mollis*	*latidens*		*latidens*				
Site	Branson Creek	Blue Basin	Blue Basin	Branson Creek	Blue Basin	Mascall	Mascall	Mascall	Mascall
Site #	3	9	9	3	9	4	4	4	4
Formation	John Day	John Day	John Day	John Day	John Day	Mascall	Mascall	Mascall	Mascall
Age	Ar1	Ar1	Ar1	Ar1	Ar1	Ba1	Ba1	Ba1	Ba1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL						21.58			
1LML	17.22	9.38	8.09	14.28	8.4				
2LML							21.44		
3LML								18.77	20.58
2UML									

Repository Specimen #	**JODA 2039**	**JODA 2047**	**JODA 2311**	**JODA 2397**	**JODA 2413**	**JODA 2419**	**JODA 2427**	**JODA 2432**	**JODA 2434**
Family	Equidae	Equidae	Canidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae		Hesperocyoninae	Anchitheriinae	Anchitheriinae	Anchitheriinae	Anchitheriinae	Equinae
Tribe									
Subtribe									
Genus				*Mesocyon*	*Parahippus*	*Parahippus*	*Parahippus*		*Merychippus*
Species				*coryphaeus*					
Site	Mascall	Mascall	Branson Creek	Branson Creek	Mascall	Mascall	Mascall	Mascall	Mascall
Site #	4	4	3	3	4	4	4	4	4
Formation	Mascall	Mascall	John Day	John Day	Mascall	Mascall	Mascall	Mascall	Mascall
Age	Ba1	Ba1	Ar1	Ar1	Ba1	Ba1	Ba1	Ba1	Ba1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL		22.56			17.38				
3LPL	17.04								
4LPL									
1LML			7.85	15.15			15.11	16.29	
2LML									
3LML						20.8			
2UML									17.41

Repository Specimen #	JODA 2435	JODA 2436	JODA 2437	JODA 2439	JODA 2443	JODA 2462	JODA 2897	JODA 3266	JODA 3531
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae	Canidae
Subfamily	Anchitheriinae	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Borophaginae	
Tribe						Equini		Phlaocyonini	
Subtribe									
Genus	*Parahippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Pliohippus*	*Miohippus*	*Phlaocyon*	
Species								*latidens*	
Site	Mascall	Mascall	Mascall	Mascall	Mascall	Rattlesnake	Foree	Blue Basin	Foree
Site #	4	4	4	4	4	5	7	9	7
Formation	Mascall	Mascall	Mascall	Mascall	Mascall	Rattlesnake	John Day	John Day	John Day
Age	Ba1	Ba1	Ba1	Ba1	Ba1	Hh2	Ar1	Ar1	Ar1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL						28.38			
3LPL									
4LPL		18.14							
1LML			15.86					7.54	7.52
2LML				16.86					
3LML					20.17		17.46		
2UML	15.54								

Repository Specimen #	JODA 3670	JODA 3684	JODA 4294	JODA 4447	JODA 4658	JODA 4793	JODA 4861	JODA 4895	JODA 4920
Family	Equidae	Canidae	Equidae	Sciuridae	Canidae	Equidae	Canidae	Equidae	Canidae
Subfamily	Anchitheriinae	Hesperocyoninae	Equinae	Sciurinae	Borophaginae	Anchitheriinae	Borophaginae	Anchitheriinae	Borophaginae
Tribe				Basal Terrestrial Squirrels	Phlaocyonini		Phlaocyonini		Phlaocyonini
Subtribe									
Genus		*Mesocyon*	*Merychippus*	*Protospermophilus*	*Phlaocyon*	*Miohippus*	*Phlaocyon*	*Miohippus*	*Phlaocyon*
Species				*vortmani*	*latidens*		*latidens*		*latidens*
Site	Foree	Logan Butte	Mascall	Hayes' Haven	Sorefoot Creek	Foree	Foree	Blue Basin	Blue Basin
Site #	7	52	4		64	7	7	9	9
Formation	John Day	John Day	Mascall	John Day	John Day	John Day	John Day	John Day	John Day
Age	Ar1	Ar1	Ba1	Ar2	Ar1	Ar1	Ar1	Ar1	Ar1
Source	Measurement	Measurement	Measurement	JXS	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL						12.4			
3LPL									
4LPL									
1LML		15.36		2.01	7.33		8.13		8.38
2LML									
3LML	17.95		21.49					15.53	
2UML									

Repository Specimen #	**JODA 5761**	**JODA 5903**	**JODA 6156**	**JODA 6215**	**JODA 6234**	**JODA 6289**	**JODA 6355**	**JODA 6464**	**JODA 6810**
Family	Sciuridae	Equidae	Equidae	Equidae	Equidae	Canidae	Sciuridae	Canidae	Canidae
Subfamily	Sciurinae	Anchitheriinae	Anchitheriinae	Anchitheriinae	Anchitheriinae	Borophaginae	Sciurinae	Borophaginae	Borophaginae
Tribe	Sciurini					Borophagini	Sciurini	Borophagini	Borophagini
Subtribe						Basal Borophagini		Basal Borophagini	Basal Borophagini
Genus	*Protosciurus*	*Miohippus*	*Miohippus*	*Miohippus*	*Mesohippus*	*Cormocyon*	*Miosciurus*	*Cormocyon*	*Cormocyon*
Species	*condoni*						*ballovianus*	*copei*	
Site	Hayes' Haven	Lonerock	Lonerock	Lonerock	BLM Land Exchange	Blue Basin	Blue Basin	Blue Basin	Sorefoot Creek
Site #		140-61	140-71	140-75	Tract 58	9		9	64
Formation	John Day	John Day	John Day	John Day	John Day	John Day	John Day	John Day	John Day
Age	Ar2	Ar2	Ar2	Ar2	Ar1	Ar1	Ar1	Ar1	Ar1
Source	JXS	Measurement	Measurement	Measurement	Measurement	Measurement	JXS	Measurement	Measurement
2LPL									
3LPL				13.75					
4LPL									
1LML	2.61		12.61			8.18	1.71	8.37	8.59
2LML									
3LML					17.58				
2UML		11.24							

Repository Specimen #	JODA 7010	JODA 7208	JODA 7368	JODA 7369	JODA 7424	JODA 8057	JODA 8266	JODA 8579	JODA 10072
Family	Equidae	Canidae	Equidae	Equidae	Equidae	Canidae	Equidae	Canidae	Equidae
Subfamily	Anchitheriinae	Borophaginae	Anchitheriinae	Anchitheriinae	Anchitheriinae	Borophaginae	Anchitheriinae	Borophaginae	Anchitheriinae
Tribe		Borophagini				Borophagini		Borophagini	
Subtribe		Basal Borophagini				Basal Borophagini		Basal Borophagini	
Genus	*Archaeohippus*	*Cormocyon*	*Miohippus*	*Miohippus*	*Archaeohippus*	*Cormocyon*	*Miohippus*	*Cormocyon*	*Kalobatippus*
Species									
Site	Bridge Creek 6	Foree	Lonerock	Lonerock	Schrock's	Blue Basin	Bone Creek (Uppermost)	North Foree	Haystack 4
Site #	160	7	140-57	140-70		9	49	7B	8A
Formation	John Day	John Day	John Day	John Day	John Day	John Day	John Day	John Day	John Day
Age	Ar2	Ar1	Ar2	Ar2	Ar1	Ar1	Ar2	Ar1	Ar1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL					12.51				
3LPL									
4LPL			11.31						
1LML		9.03				8.91		8.01	
2LML									
3LML	14.79						17.47		
2UML				11.3					13.09

Repository Specimen #	JODA 10093	JODA 10260	JODA 10300	JODA 10353	JODA 13004	LACM 1541	LACM 5933	LACM 5937	LACM 6588
Family	Sciuridae	Canidae	Canidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Sciurinae		Borophaginae		Anchitheriinae	Equinae	Equinae	Anchitheriinae	Equinae
Tribe	Sciurini		Phlaocyonini						Equini
Subtribe									
Genus	*Miosciurus*		*Rhizocyon*		*Miohippus*	*Merychippus*	*Merychippus*	*Archaeohippus*	*Pliohippus*
Species	*ballovianus*								
Site	Blue Basin	Blue Basin	Blue Basin	Blue Basin	Blue Basin	Skull Springs	Mascall General	Mascall General	Rome
Site #		9	9	9	9	CIT 57	1869	1869	CIT 62
Formation	John Day	John Day	John Day	John Day	John Day	Battle Creek	Mascall	Mascall	Drewsey
Age	Ar1	Ar1	Ar1	Ar1	Ar1	Ba2	Ba1	Ba1	Hh2
Source	JXS	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	1.67	7.19	8.85	8.13					
2LML									
3LML					16.49	23.59	21.5	19.08	28.35
2UML									

Repository Specimen #	LACM 6590	LACM 6591	LACM 6593	LACM 12311	LACM 32237	LACM 32238	LACM 32546	LACM 32591	LACM 32593
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Hipparionini					
Subtribe									
Genus	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Nannipus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species									
Site	Rome	Rome	Rome	Arlington	Skull Springs	Skull Springs	Skull Springs	Skull Springs	Skull Springs
Site #	CIT 62	CIT 62	CIT 62	6420	CIT 124	CIT 124	CIT 57	CIT 57	CIT 57
Formation	Drewsey	Drewsey	Drewsey	Alkali Canyon	Battle Creek	Battle Creek	Battle Creek	Battle Creek	Battle Creek
Age	Hh2	Hh2	Hh2	Hh3	Ba2	Ba2	Ba2	Ba2	Ba2
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL					19.43	13.73			
3LPL									
4LPL									
1LML									
2LML									
3LML	28.62	27.81	28.07	23.9			22.63	21.01	22.11
2UML									

Repository Specimen #	**LACM 32596**	**LACM 32602**	**LACM 32605**	**LACM 32608**	**LACM 32627**	**LACM 32631**	**LACM 32633**	**LACM 32661**	**LACM 32678**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe									
Subtribe									
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species									
Site	Skull Springs	Skull Springs	Skull Springs	Skull Springs	Skull Springs	Skull Springs	Skull Springs	Skull Springs	Skull Springs
Site #	CIT 57	CIT 57	CIT 57	CIT 57	CIT 57	CIT 57	CIT 57	CIT 57	CIT 57
Formation	Battle Creek	Battle Creek	Battle Creek	Battle Creek	Battle Creek	Battle Creek	Battle Creek	Battle Creek	Battle Creek
Age	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	21.03								
3LPL									
4LPL									
1LML									
2LML									
3LML		21.9	21.77	21.08	22.68	23.05	22.13	22.63	22.98
2UML									

Repository Specimen #	LACM 32679	LACM 32686	LACM 32696	LACM 32818	LACM 33194	LACM 33580	LACM 55211	LACM 55212	LACM 58168
Family	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae	Canidae	Canidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Borophaginae	Equinae	Caninae	Caninae	Equinae
Tribe					Borophagini		Vulpini	Canini	Equini
Subtribe					Aelurodontina			Canina	
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Tomarctus*	*Merychippus*	*Vulpes*	*Eucyon*	*Pliohippus*
Species							*stenognathus*	*davisi*	
Site	Skull Springs	Skull Springs	Skull Springs	Skull Springs	Gateway	Beatty Buttes	Thousand Creek	Hoffman Blowout	Hoffman Blowout
Site #	CIT 57	CIT 124	3171	CIT 57	CIT 368	CIT 371	CIT 63	6421	6421
Formation	Battle Creek	Battle Creek	Battle Creek	Battle Creek	Mascall	Beatty Butte	Thousand Creek	Alkali Canyon	Alkali Canyon
Age	Ba2	Ba2	Ba2	Ba2	Ba1	Ba1	Hh1	Hh3	Hh3
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL			18.25						30.28
3LPL									
4LPL									
1LML					19.7		12.76	13.69	
2LML									
3LML	20.25	19.96		22.5		22.39			
2UML									

Repository Specimen #	LACM 58173	LACM 92992	LACM 93891	LACM 94504	LACM 94518	LACM CIT 1045	LACM CIT 1046	LACM CIT 1053	LACM CIT 1055
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Anchitheriinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Equini	Equini	Equini			Hipparionini	Hipparionini
Subtribe									
Genus	*Neohipparion*	*Neohipparion*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Desmatippus*	*Desmatippus*	*Acritohippus*	*Acritohippus*
Species						*avus*	*avus*	*isonesus*	*isonesus*
Site	Hoffman Blowout	Stinking Water Creek	North Bartlett Mountain	Bartlett Mountain	Bartlett Mountain	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek
Site #	6421	CIT 41	CIT 595	3762	3762	CIT 44	CIT 44	CIT 44	CIT 44
Formation	Alkali Canyon	Drewsey	Drewsey	Drewsey	Drewsey	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek
Age	Hh3	Hh2	Hh2	Hh2	Hh2	Ba1	Ba1	Ba1	Ba1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL		22.18				19.25			
3LPL									
4LPL			29.9						
1LML									19.92
2LML									
3LML	26.44				31.43		20.67		
2UML				26.99				19.79	

Repository	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**
Specimen #	**CIT 1056**	**CIT 1057**	**CIT 1058**	**CIT 1059**	**CIT 1123**	**CIT 1124**	**CIT 1769**	**CIT 1770**	**CIT 2697**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Equinae	Anchitheriinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini		Hipparionini	
Subtribe									
Genus	*Acritohippus*	*Acritohippus*	*Acritohippus*	*Acritohippus*	*Merychippus*	*Merychippus*	*Hypohippus*	*Merychippus*	*Parahippus*
Species	*isonesus*	*isonesus*	*isonesus*	*isonesus*	*brevidontus*	*brevidontus*	*osborni*	*brevidontus*	*pawniensis*
Site	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Mecca
Site #	CIT 44	CIT 44	CIT 44	CIT 44	CIT 44	CIT 44	CIT 44	CIT 58	CIT 37
Formation	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	John Day
Age	Ba1	Ba1	Ba1	Ba1	Ba1	Ba1	Ba1	Ba1	Ar4
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL		18.39		19.41		19.89			
3LPL									
4LPL									
1LML									
2LML	19.17								
3LML			23.84				23.03		
2UML					19.37			18.91	16.23

Repository	LACM	LACM	LACM	LACM	LACM	LACM	LACM	LACM	LACM
Specimen #	**CIT 2698**	**CIT 2699**	**CIT 2705**	**CIT 2930**	**CIT 3054**	**CIT 3055**	**CIT 3057**	**CIT 3062**	**CIT 3063**
Family	Equidae	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Anchitheriinae	Anchitheriinae		Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae
Tribe				Hipparionini		Equini	Hipparionini	Equini	
Subtribe									
Genus	*Parahippus*	*Parahippus*		*Merychippus*	*Merychippus*	*Pliohippus*	*Acritohippus*	*Pliohippus*	*Hypohippus*
Species	*pawniensis*	*pawniensis*		*seversus*		*mirabilis*	*isonesus*	*mirabilis*	*osborni*
Site	Mecca	Mecca	Mecca	Gateway	Beatty Buttes	Beatty Buttes	Beatty Buttes	Beatty Buttes	Beatty Buttes
Site #	CIT 37	CIT 37	CIT 37a	CIT 368	CIT 371	CIT 371	CIT 371	CIT 371	CIT 371
Formation	John Day	John Day	John Day	Mascall	Beatty Butte	Beatty Butte	Beatty Butte	Beatty Butte	Beatty Butte
Age	Ar4	Ar4	Ar4	Ba1	Ba1	Ba1	Ba1	Ba1	Ba1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL								21.21	
1LML	14.51		17			21.41			
2LML									
3LML		16.24			23.54		24.15		24.77
2UML				18.34					

Repository Specimen #	**LACM CIT 3067**	**LACM CIT 3201**	**LACM CIT 3202**	**LACM CIT 3207**	**LACM CIT 340**	**LACM CIT 392**	**LACM CIT 4081**	**LACM CIT 4090**	**LACM CIT 4095**
Family	Canidae	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae	Equidae	Equidae
Subfamily		Equinae	Equinae	Equinae	Equinae	Borophaginae	Equinae	Equinae	Anchitheriinae
Tribe				Equini	Hipparionini	Borophagini	Hipparionini	Hipparionini	
Subtribe						Cynarctina			
Genus		*Merychippus*	*Merychippus*	*Pliohippus*	*Acritohippus*	*Euoplocyon*	*Acritohippus*	*Merychippus*	*Archaeohippus*
Species				*mirabilis*	*isonesus*	*brachygnathus*	*isonesus*	*brevidontus*	*ultimus*
Site	Beatty Buttes	Corral Buttes	Corral Buttes	Corral Buttes	Skull Springs	Skull Springs	Skull Springs	Virgin Valley	Gateway
Site #	CIT 371	CIT 417	CIT 417	CIT 418	CIT 57	CIT 57	CIT 57	CIT 114	CIT 368
Formation	Beatty Butte	Butte Creek	Butte Creek	Butte Creek	Battle Creek	Butte Creek	Butte Creek	Virgin Valley	Mascall
Age	Ba1	Ba1	Ba1	Ba1	Ba2	Ba2	Ba2	Ba1	Ba1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	10.57			18.37	15.71	17.58		16.72	
2LML									
3LML		21.63	23.67				21.64		14.91
2UML									

Repository Specimen #	LACM CIT 4096	LACM CIT 425	LACM CIT 437	LACM CIT 4916	LACM CIT 5011	LACM CIT 5188	LACM CIT 5239	LACM CIT 53	LACM CIT 532
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Sciuridae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Equinae	Sciurinae	Equinae	Equinae
Tribe			Hipparionini	Hipparionini			Marmotini	Hipparionini	Hipparionini
Subtribe									
Genus	*Merychippus*	*Merychippus*	*Acritohippus*	*Merychippus*	*Hypohippus*	*Merychippus*	*Spermophilus*	*Neohipparion*	*Merychippus*
Species			*isonesus*	*seversus*			*shotwelli*	*leptode*	*seversus*
Site	Gateway	Dayville	Sucker Creek	Gateway	Beatty Buttes	Corral Buttes	Arlington	Thousand Creek	Mascall Type
Site #	CIT 368	CIT 113	CIT 44	CIT 368	CIT 371	CIT 417		CIT 63	CIT 532
Formation	Mascall	Mascall	Sucker Creek	Mascall	Beatty Butte	Butte Creek	Alkali Canyon	Thousand Creek	Mascall
Age	Ba1	Ba1	Ba1	Ba1	Ba1	Ba1	Hh3	Hh1	Ba1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Black 1963	Measurement	Measurement
2LPL		19							
3LPL									
4LPL									
1LML					21.93	18.39	2.5	23.05	
2LML									
3LML	16.19								
2UML			22.11	19.48					19.26

Repository Specimen #	LACM CIT 5454	LACM CIT4067	SCNHM VMC 197	SCNHM VMC 197	SCNHM VMO 165 A	SCNHM VMO 367	SCNHM VMO 444 t4	SCNHM VMO 520	SCNHM VMO 800 B
Family	Equidae	Equidae	Canidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Anchitheriinae	Equinae	Borophaginae	Borophaginae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe			Borophagini	Borophagini					
Subtribe									
Genus	*Parahippus*	*Merychippus*							
Species	*pawniensis*								
Site	Mecca	Dayville	Fly Canyon						
Site #	CIT 37	CIT 113							
Formation	John Day	Mascall	High Rock Sequence	High Rock Sequence	High Rock Sequence	High Rock Sequence	High Rock Sequence	High Rock Sequence	High Rock Sequence
Age	Ar4	Ba1	Hf2	Hf2	Hf2	Hf2	Hf2	Hf2	Hf2
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									19.94
3LPL	13.99								
4LPL									
1LML			21.17	13.28		16.85			
2LML									
3LML		20.66			24.19		22.78		
2UML								20.49	

Repository	**SCNHM**	**SCNHM**	**SDSM**	**SDSM**	**SDSM**	**SDSM**	**SDSM**	**SDSM**	**SDSM**
Specimen #	**VMO 811 B**	**VMO 819**	**10607**	**16742**	**16744**	**16753**	**16756**	**16757**	**66313**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe			Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus			*Hipparion*	*Hipparion*	*Hipparion*	*Hipparion*	*Nannipus*	*Hipparion*	*Hipparion*
Species			*condoni*	*condoni*	*condoni*	*condoni*		*condoni*	
Site			Buena	Toppenish-Goldendale	Buena	Moxee	Toppenish-Goldendale	Buena	Horse Locality
Site #			6414	6415	6414	6425	6419	6414	6367
Formation	High Rock Sequence	High Rock Sequence	Ellensburg	Ellensburg	Ellensburg	Ellensburg	Ellensburg	Ellensburg	Ellensburg
Age	Hf2	Hf2	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL					23.82				
3LPL									
4LPL							18.58		24.22
1LML			23.28					19.72	
2LML				23.54					
3LML	20.08	21.61				21.71			
2UML									

Repository Specimen #	UALP 18304	UALP 18351	UALP 18497	UALP 18893	UCMP 156	UCMP 499	UCMP 1178	UCMP 1618	UCMP 1625
Family	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Sciurinae	Sciurinae	Sciurinae	Sciurinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Basal Terrestrial Squirrels	Basal Terrestrial Squirrels	Marmotini	Basal Terrestrial Squirrels	Hipparionini		Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Protospermophilus*	*Protospermophilus*	*Spermophilus*	*Protospermophilus*	*Neohipparion*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species	*malheurensis*	*malheurensis*	*tephrus*	*malheurensis*			*seversus*	*seversus*	*seversus*
Site	Devils Gate	Devils Gate	Devils Gate	Devils Gate	JCM 4	Mascall Misc. 2	Mascall General	Mascall Misc. 2	Mascall Misc. 2
Site #	8879	8963	8955	9057	817	884	67153	884	884
Formation	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Rattlesnake	Mascall	Mascall	Mascall	Mascall
Age	Ba1	Ba1	Ba1	Ba1	Hh2	Ba1	Ba1	Ba1	Ba1
Source	Downing 1992	Downing 1992	Downing 1992	Downing 1992	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL						15.86		19.14	
3LPL									
4LPL									
1LML	2.42	2.23	1.86	1.92			15.76		
2LML									
3LML					25.55				18.26
2UML									

Repository Specimen #	**UCMP 1707**	**UCMP 1718**	**UCMP 2028**	**UCMP 2202**	**UCMP 10665**	**UCMP 11306**	**UCMP 11450**	**UCMP 11474**	**UCMP 11562**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae	Canidae	Canidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Borophaginae	Equinae	Borophaginae	Borophaginae
Tribe		Hipparionini	Hipparionini	Hipparionini		Borophagini		Borophagini	Borophagini
Subtribe						Cynarctina		Cynarctina	Cynarctina
Genus	*Merychippus*	*Acritohippus*	*Merychippus*	*Neohipparion*	*Hypohippus*	*Metatomarctus*	*Merychippus*	*Paracynarctus*	*Paracynarctus*
Species		*isonesus*	*seversus*		*osborni*	*sp. A*		*kelloggi*	*kelloggi*
Site	Schneider Ranch	Schneider Ranch	Schneider Ranch	Rattlesnake General	Virgin Valley	Virgin Valley	Virgin Valley 9	Virgin Valley	Virgin Valley
Site #	903	903	903	6553	1065	1065	3351	1065	1065
Formation	Mascall	Mascall	Mascall	Rattlesnake	Virgin Valley	Virgin Valley	Virgin Valley	Virgin Valley	Virgin Valley
Age	Ba1	Ba1	Ba1	Hh2	Ba1	Ba1	Ba1	Ba1	Ba1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	22.17				24.6				
3LPL									
4LPL									
1LML						16.6		19.31	14.55
2LML									
3LML		21.05	20.72	25.2			19.9		
2UML									

Repository Specimen #	UCMP 11699	UCMP 11704	UCMP 12506	UCMP 12538	UCMP 12570	UCMP 12587	UCMP 19414	UCMP 22351	UCMP 22378
Family	Equidae	Equidae	Sciuridae	Sciuridae	Sciuridae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Sciurinae	Sciurinae	Sciurinae	Anchitheriinae	Equinae	Equinae	Equinae
Tribe			Marmotini	Marmotini	Marmotini		Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus Species	*Merychippus*	*Merychippus*	*Paenemarmota nevadensis*	*Marmota minor*	*Spermophilus*	*Hypohippus osborni*	*Neohipparion leptode*	*Hipparion anthonyi*	*Cormohipparion occidentale*
Site	Virgin Valley 13	Virgin Valley 13	Thousand Creek	Thousand Creek	Thousand Creek	Virgin Valley 4	Thousand Creek 8	Ironside	Rattlesnake 9
Site #	1094	1094		1083		1085	1101	3037	3057
Formation	Virgin Valley	Virgin Valley	Thousand Creek	Thousand Creek	Thousand Creek	Virgin Valley	Thousand Creek	Juntura	Rattlesnake
Age	Ba1	Ba1	Hh1	Hh1	Hh1	Ba1	Hh1	Cl3	Hh2
Source	Measurement	Measurement	Kellogg 1910	Black 1963	Kellogg 1910	Measurement	Measurement	Measurement	Measurement
2LPL	20.64	20.65					29.04	27.75	
3LPL									
4LPL									
1LML			6.3	3.5	1.9	20.17			
2LML									
3LML									25.05
2UML									

Repository Specimen #	UCMP 22388	UCMP 22391	UCMP 22400	UCMP 22423	UCMP 23088	UCMP 23098	UCMP 23106	UCMP 23108	UCMP 26793
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Sciuridae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Sciurinae
Tribe	Equini	Equini	Equini	Equini	Hipparionini	Hipparionini			Marmotini
Subtribe									
Genus	*Pliohippus*	*Pliohippus*	*Dinohippus*	*Dinohippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Spermophilus*
Species	*spectans*	*spectans*	*tantalus*	*tantalus*	*seversus*	*seversus*			*gidleyi*
Site	Rattlesnake 11	Rattlesnake 11	Rattlesnake 9	Thousand Creek 20	Mascall 5	Mascall 1	Mascall 5	Mascall 5	Rattlesnake
Site #	3060	3060	3057	2744	3059	3043	3059	3059	
Formation	Rattlesnake	Rattlesnake	Rattlesnake	Thousand Creek	Mascall	Mascall	Mascall	Mascall	Rattlesnake
Age	Hh2	Hh2	Hh2	Hh1	Ba1	Ba1	Ba1	Ba1	Hh2
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Black 1963
2LPL			28.58			19.46			
3LPL									
4LPL							17.05		
1LML	24.72								1.8
2LML									
3LML				31.27				20.44	
2UML		24.72			20.23				

Repository Specimen #	UCMP 27126	UCMP 29956	UCMP 29957	UCMP 29962	UCMP 29963	UCMP 29966	UCMP 29969	UCMP 32753	UCMP 37142
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae		Caninae	Equinae	Equinae
Tribe	Hipparionini	Equini	Hipparionini	Equini	Equini		Vulpini	Hipparionini	
Subtribe									
Genus	*Neohipparion*	*Pliohippus*	*Neohipparion*	*Pliohippus*	*Pliohippus*		*Vulpes*	*Merychippus*	*Merychippus*
Species	*leptode*						*stenognathus*	*seversus*	
Site	Thousand Creek	Rattlesnake 9	JCM 2	Rattlesnake 11	Rattlesnake 11	Rattlesnake 9	Rattlesnake 3	Gateway	Dry Creek
Site #	6571	3057	815	3060	3060	3057	3042	3472	3938
Formation	Thousand Creek	Rattlesnake	Rattlesnake	Rattlesnake	Rattlesnake	Rattlesnake	Rattlesnake	Mascall	Deer Butte
Age	Hh1	Hh2	Hh2	Hh2	Hh2	Hh2	Hh2	Ba1	Ba2
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL				31.61					
3LPL									
4LPL					29.31				
1LML	22.95						13.55		19.37
2LML									
3LML		27.62	30.88			30.99			
2UML								18.19	

Repository Specimen #	UCMP 39093	UCMP 39095	UCMP 40315	UCMP 61616	UCMP 61623	UCMP 61750	UCMP 76367	UCMP 76608	UCMP 76855
Family	Sciuridae	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae	Canidae	Equidae
Subfamily	Sciurinae	Equinae	Equinae	Anchitheriinae	Anchitheriinae	Borophaginae	Anchitheriinae	Borophaginae	
Tribe	Basal Terrestrial Squirrels	Hipparionini	Hipparionini			Borophagini		Borophagini	
Subtribe						Aelurodontina		Basal Borophagini	
Genus	*Protospermophilus*	*Merychippus*	*Merychippus*	*Hypohippus*	*Parahippus*	*Tomarctus*	*Miohippus*	*Cormocyon*	
Species	*oregonensis*	*seversus*	*seversus*					*copei*	
Site	Mascall	Mascall 16	Crooked River 2	Massacre Lake	Massacre Lake	Massacre Lake	Stubblefield 3	Picture Gorge 7	Drees 2
Site #	4828	4830	4949	6161	6161	6161	6660	6681	76124
Formation	Mascall	Mascall	Mascall	High Rock Sequence	High Rock Sequence	High Rock Sequence	John Day	John Day	John Day
Age	Ba1	Ba1	Ba1	Hf2	Hf2	Hf2	Ar2	Ar1	Hf1
Source	Downs 1956	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL				19.56					
1LML	2.9	19.01				15.22		11.37	11.6
2LML									
3LML			22.11				15.24		
2UML					13.68				

Repository Specimen #	**UCMP 77161**	**UCMP 315400**	**UCMP 315413**	**UCMP 315689**	**UCMP 316450**	**UCMP 316451**	**UCMP 316833**	**UCMP 316500b**	**UO 173**
Family	Canidae	Equidae	Equidae	Equidae	Sciuridae	Sciuridae	Equidae	Sciuridae	Equidae
Subfamily	Borophaginae	Anchitheriinae	Anchitheriinae	Anchitheriinae	Sciurinae	Sciurinae	Anchitheriinae	Sciurinae	Equinae
Tribe	Borophagini				Basal Terrestrial Squirrels	Basal Terrestrial Squirrels		Marmotini	Hipparionini
Subtribe	Basal Borophagini								
Genus	*Cormocyon*	*Parahippus*	*Parahippus*	*Parahippus*	*Protospermophilus*	*Protospermophilus*	*Parahippus*	*Miospermophilus*	*Neohipparion*
Species	*copei*	*pawniensis*	*pawniensis*	*pawniensis*			*leonensis*		
Site	Haystack 8	Massacre Lake 1	Massacre Lake 1	Massacre Lake 1	Massacre Lake	Massacre Lake	Warm Springs 1	Massacre Lake	
Site #	6322	RV7043	RV7043	RV7043	RV 7043	RV 7043	RV7314	RV 7043	
Formation	John Day	High Rock Sequence	High Rock Sequence	High Rock Sequence	Virgin Valley	Virgin Valley	John Day	Virgin Valley	Rattlesnake
Age	Ar2	Hf2	Hf2	Hf2	Hf2	Hf2	Ar4	Hf2	Hh2
Source	Measurement	Measurement	Measurement	Measurement	Morea 1981	Morea 1981	Measurement	Morea 1981	Measurement
2LPL			16.37						
3LPL									
4LPL									
1LML	12.42			15.06	2.2	2.9		2.2	
2LML									
3LML							15.76		26.94
2UML		14.38							

Repository Specimen #	**UO 191**	**UO 197**	**UO 2786**	**UO 3241**	**UO 3596**	**UO 3625**	**UO 3627**	**UO 3627**	**UO 4097**
Family	Equidae	Equidae	Equidae	Canidae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae
Subfamily	Equinae	Equinae	Equinae	Caninae	Sciurinae	Sciurinae	Sciurinae	Sciurinae	Sciurinae
Tribe	Equini	Equini		Canini	Marmotini	Marmotini	Marmotini	Marmotini	Marmotini
Subtribe				Canina					
Genus	*Pliohippus*	*Pliohippus*	*Merychippus*	*Eucyon*	*Spermophilus*	*Parapaenemarmota*	*Spermophilus*	*Spermophilus*	*Spermophilus*
Species	*spectans*	*spectans*		*davisi*	*shotwelli*	*oregonensis*	*mckayensis*	*mckayensis*	*wilsoni*
Site		John Day Pliocene	Gateway	McKay Reservoir	McKay Reservoir	McKay Reservoir	McKay Reservoir	McKay Reservoir	Ellensburg
Site #			2243	2222					6507
Formation	Rattlesnake	Rattlesnake	Mascall	McKay	McKay	McKay	McKay	McKay	Ellensburg
Age	Hh2	Hh2	Ba1	Hh3	Hh3	Hh3	Hh3	Hh3	Cl3
Source	Measurement	Measurement	Measurement	Measurement	Black 1963	Shotwell 1956	Black 1963	Shotwell 1956	Black 1963
2LPL		26.39							
3LPL									
4LPL									
1LML			16.44	16.33	2.4	4.8	2	1.8	2.4
2LML									
3LML	21.59								
2UML									

Repository Specimen #	UO 4097	UO 4975	UO 5159	UO 5566	UO 5763	UO 5871	UO 6171	UO 6667	UO 7964
Family	Sciuridae	Equidae	Equidae	Equidae	Sciuridae	Sciuridae	Equidae	Equidae	Sciuridae
Subfamily	Sciurinae	Equinae	Equinae		Sciurinae	Sciurinae			Sciurinae
Tribe	Marmotini				Marmotini	Marmotini			Marmotini
Subtribe									
Genus	*Spermophilus*	*Merychippus*	*Merychippus*		*Ammospermophilus*	*Ammospermophilus*			*Spermophilus*
Species	*wilsoni*				*junturensis*	*junturensis*			*shotwelli*
Site	McKay Reservoir		Mascall	Poison Basin	Juntura	Juntura	Poison Basin	Poison Basin	Westend Blowout
Site #				2340	2341	2336	2343	2354	
Formation	McKay	Mascall	Mascall	Juntura	Juntura	Juntura	Juntura	Juntura	Alkali Canyon
Age	Hh3	Ba1	Ba1	Cl3	Cl3	Cl3	Cl3	Cl3	Hh3
Source	Shotwell 1956	Measurement	Measurement	Measurement	Russell 1956	Russell 1956	Measurement	Measurement	Black 1963
2LPL		21.42							
3LPL									
4LPL									
1LML	1.9			21.92	1.3	1.3			2.4
2LML									
3LML			20.76				24.72	23.97	
2UML									

Repository Specimen #	UO 7965	UO 7966	UO 7969	UO 10283	UO 11020	UO 15270	UO 17081	UO 19902	UO 20508
Family	Sciuridae	Sciuridae	Sciuridae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Sciurinae	Sciurinae	Sciurinae	Equinae		Equinae	Equinae	Equinae	Equinae
Tribe	Marmotini	Marmotini	Marmotini	Hipparionini					
Subtribe									
Genus	*Spermophilus*	*Spermophilus*	*Spermophilus*	*Hipparion*		*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species	*shotwelli*	*shotwelli*	*shotwelli*						
Site	Westend Blowout	Westend Blowout	Westend Blowout	Black Butte	Black Butte	Cottonwood Creek	Crooked River	Skull Spring	Red Basin
Site #				2448	248		AF23-6	2467	
Formation	Alkali Canyon	Alkali Canyon	Alkali Canyon	Juntura	Juntura	Mascall	Mascall	Battle Creek	Butte Creek
Age	Hh3	Hh3	Hh3	Cl3	Cl3	Ba1	Ba1	Ba2	Ba2
Source	Black 1963	Black 1963	Black 1963	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL						19.27			
3LPL									19.39
4LPL									
1LML	2.3	2.5	2.4	22.65	19.87			17.12	
2LML									
3LML							21.63		
2UML									

Repository Specimen #	UO 20509	UO 20552	UO 20617	UO 20631	UO 20646	UO 20647	UO 20946	UO 21038	UO 21353
Family	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae
Subfamily	Equinae	Borophaginae	Anchitheriinae	Equinae	Equinae	Equinae	Equinae	Equinae	Borophaginae
Tribe		Borophagini							Borophagini
Subtribe		Cynarctina							Borophagina
Genus	*Merychippus*	*Tephrocyon*	*Hypohippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Epicyon*
Species		*rurestris*							*saevus*
Site	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Dalles
Site #									
Formation	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Chenoweth
Age	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Cl3
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL			23.08						
3LPL									
4LPL									
1LML		18.64			19.29	18.11	21.02	19.16	26.01
2LML	18								
3LML									
2UML				20.12					

Repository Specimen #	UO 21559	UO 22749	UO 22784	UO 22846	UO 22993	UO 23060	UO 23159	UO 23322	UO 23323
Family	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Borophaginae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Borophagini							Equini	
Subtribe	Cynarctina								
Genus	*Paracynarctus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species	*kelloggi*								
Site	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin
Site #	2494								
Formation	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek
Age	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL			20.78						
4LPL									
1LML	17.96	17.7			18.27	16.72	15.97		17.51
2LML									
3LML				23.86					
2UML								18.39	

Repository Specimen #	UO 23324	UO 23345	UO 23358	UO 23437	UO 23456	UO 23486	UO 23548	UO 23704	UO 23709
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe								Equini	
Subtribe									
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species									
Site	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin
Site #									
Formation	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek
Age	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL							20.79		
4LPL									
1LML	17.96	15.89	15.05	19.71	18.44	18.01			19.88
2LML									
3LML									
2UML								17.88	

Repository Specimen #	UO 23710	UO 23776	UO 23794	UO 23834	UO 23841	UO 23842	UO 23897	UO 24191	UO 24236
Family	Equidae	Equidae	Equidae	Equidae	Canidae	Canidae	Equidae	Canidae	Sciuridae
Subfamily	Equinae	Equinae	Equinae	Equinae	Borophaginae	Borophaginae	Anchitheriinae	Borophaginae	Sciurinae
Tribe					Borophagini	Borophagini		Borophagini	Basal Terrestrial Squirrels
Subtribe					Cynarctina	Cynarctina		Cynarctina	
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Paracynarctus*	*Paracynarctus*	*Hypohippus*	*Tephrocyon*	*Protospermophilus*
Species					*kelloggi*	*kelloggi*		*rurestris*	*malheurensis*
Site	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin
Site #								2495	2495
Formation	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek
Age	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Shotwell 1968
2LPL									
3LPL									
4LPL							20.32		
1LML	18.96				18.36	17.66		17.97	1.88
2LML				17.9					
3LML		24.11	20.9						
2UML									

Repository Specimen #	UO 24240	UO 24246	UO 24248	UO 24250	UO 24251	UO 24256	UO 24260	UO 24261	UO 24404
Family	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae
Subfamily	Sciurinae	Sciurinae	Sciurinae	Sciurinae	Sciurinae	Sciurinae	Sciurinae	Sciurinae	Sciurinae
Tribe	Marmotini	Marmotini	Basal Terrestrial Squirrels	Marmotini	Basal Terrestrial Squirrels	Marmotini	Basal Terrestrial Squirrels	Basal Terrestrial Squirrels	Basal Terrestrial Squirrels
Subtribe									
Genus Species	*Spermophilus tephrus*	*Spermophilus tephrus*	*Protospermophilus malheurensis*	*Spermophilus tephrus*	*Protospermophilus malheurensis*	*Spermophilus tephrus*	*Protospermophilus malheurensis*	*Protospermophilus malheurensis*	*Protospermophilus malheurensis*
Site	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin	Red Basin
Site #			2495		2495		2495	2495	2495
Formation	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek	Butte Creek
Age	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2	Ba2
Source	Shotwell 1968	Shotwell 1968	Shotwell 1968	Shotwell 1968	Shotwell 1968	Shotwell 1968	Shotwell 1968	Shotwell 1968	Shotwell 1968
2LPL									
3LPL									
4LPL									
1LML	2	1.79	2	1.97	1.82	1.96	1.76	1.89	1.91
2LML									
3LML									
2UML									

Repository Specimen #	**UO 24572**	**UO 24573**	**UO 24984**	**UO 27015**	**UO 30993**	**UO 36606**	**UO 42501**	**UO Y-672**	**UWBM 31452**
Family	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Equidae	Canidae	Canidae	Equidae	Equidae
Subfamily	Sciurinae	Sciurinae	Sciurinae	Sciurinae	Equinae	Caninae	Borophaginae	Equinae	Anchitheriinae
Tribe	Tamiini	Tamiini	Marmotini	Marmotini	Hipparionini	Canini	Borophagini	Hipparionini	
Subtribe						Canina	Borophagina		
Genus	*Tamias*	*Tamias*	*Spermophilus*	*Spermophilus*	*Neohipparion*	*Eucyon*	*Epicyon*	*Hipparion*	*Parahippus*
Species			*wilsoni*			*davisi*	*saevus*	*condoni*	
Site	Juntura	Juntura	Bartlett Mountain	Little Valley	Rattlesnake	Juniper Creek	Black Butte	Ellensburg	Picture Gorge 36
Site #	2500	2500	2517	2516		2469			A5835
Formation	Juntura	Juntura	Drewsey	Chalk Butte	Rattlesnake	Grassy Mountain	Juntura	Ellensburg	John Day
Age	Cl3	Cl3	Hh2	Hh3	Hh2	Hh2	Cl3	Cl3	Ar2
Source	Shotwell 1970	Shotwell 1970	Shotwell 1956	Shotwell 1956	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	1.42	1.17	2.42	1.88		16.46	29.1	17.7	13.5
2LML									
3LML					30.5				
2UML									

Repository Specimen #	UWBM 39225	UWBM 39226	UWBM 39280	UWBM 40019	UWBM 40136	UWBM 40738	UWBM 40931	UWBM 42265	UWBM 42266
Family	Canidae	Canidae	Sciuridae	Sciuridae	Equidae	Canidae	Equidae	Canidae	Sciuridae
Subfamily			Sciurinae	Sciurinae	Equinae		Equinae	Caninae	Sciurinae
Tribe			Marmotini	Marmotini	Equini			Canini	Marmotini
Subtribe								Canina	
Genus					*Pliohippus*		*Merychippus*	*Eucyon*	
Species								*davisi*	
Site	Wildcat Creek	Wildcat Creek	Ordnance	Ordnance	Ordnance	Wildcat Creek	Rainbow Ridge	Ordnance	Ordnance
Site #	A8762	A8762	A8803	A8803	A8803	A8762	A2381	A8803	A8803
Formation	Ohanapecosh	Ohanapecosh	Alkali Canyon	Alkali Canyon	Alkali Canyon	Ohanapecosh	Virgin Valley	Alkali Canyon	Alkali Canyon
Age	Ar2	Ar2	Hh3	Hh3	Hh3	Ar2	Ba1	Hh3	Hh3
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	10.64	15.17	1.93	1.68		10.64		16.23	2.28
2LML					26.41		21.85		
3LML									
2UML									

Repository Specimen #	UWBM 42690	UWBM 42691	UWBM 42694	UWBM 42695	UWBM 42696	UWBM 42697	UWBM 42699	UWBM 44434	UWBM 46638
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Caninae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini		Canini
Subtribe									Canina
Genus	*Hipparion*	*Hipparion*	*Hipparion*	*Hipparion*	*Hipparion*	*Hipparion*	*Hipparion*	*Merychippus*	*Eucyon*
Species									*davisi*
Site	Zillah	Zillah	Zillah	Zillah	Zillah	Zillah	Zillah	Mascall	Ordnance
Site #	A9429	A9429	A9429	A9429	A9429	A9429	A9429	A9762	A8803
Formation	Ellensburg	Ellensburg	Ellensburg	Ellensburg	Ellensburg	Ellensburg	Ellensburg	Mascall	Alkali Canyon
Age	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3	Ba1	Hh3
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	26.74								
3LPL									
4LPL		24.47	19.74	21.18					
1LML					21.1	23.19	23.58	19.19	16.71
2LML									
3LML									
2UML									

Repository Specimen #	UWBM 46671	UWBM 46672	UWBM 46673	UWBM 46675	UWBM 46676	UWBM 47552	UWBM 48183	UWBM 48584	UWBM 50158
Family	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Canidae	Equidae	Canidae	Sciuridae
Subfamily	Sciurinae	Sciurinae	Sciurinae	Sciurinae	Sciurinae		Anchitheriinae		
Tribe	Marmotini	Marmotini	Marmotini	Marmotini	Marmotini				
Subtribe									
Genus	*Spermophilus*	*Spermophilus*	*Spermophilus*	*Spermophilus*	*Spermophilus*		*Miohippus*		
Species	*wilsoni*								
Site	Ordnance	Ordnance	Ordnance	Ordnance	Ordnance	Picture Gorge 29	Morgan's Locality 1	China East	Ordnance
Site #	A8803	A8803	A8803	A8803	A8803	A9596	B1511	B1515	A8803
Formation	Alkali Canyon	Alkali Canyon	Alkali Canyon	Alkali Canyon	Alkali Canyon	John Day	John Day	John Day	Alkali Canyon
Age	Hh3	Hh3	Hh3	Hh3	Hh3	Ar1	Ar1	Ar3	Hh3
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	1.97	2.03	2.12	2.64	2.03	10.31	12.71	7.64	2.08
2LML									
3LML									
2UML									

Repository Specimen #	**UWBM 50467**	**UWBM 50477**	**UWBM 50478**	**UWBM 50807**	**UWBM 51303**	**UWBM 53390**	**UWBM 53392**	**UWBM 53416**	**UWBM 53424**
Family	Sciuridae	Sciuridae	Sciuridae	Canidae	Sciuridae	Equidae	Canidae	Equidae	Equidae
Subfamily					Sciurinae	Anchitheriinae		Anchitheriinae	Anchitheriinae
Tribe					Marmotini				
Subtribe									
Genus						*Miohippus*		*Miohippus*	*Miohippus*
Species									
Site	Ordnance	Ordnance	Ordnance	Arlington 3	Ordnance	Picture Gorge 29	Picture Gorge 36	Picture Gorge 36	Picture Gorge 20
Site #	A8803	A8803	A8803	B1532	A8803	A9596	A5835	A5835	A4556
Formation	Alkali Canyon	Alkali Canyon	Alkali Canyon	Alkali Canyon	Alkali Canyon	John Day	John Day	John Day	John Day
Age	Hh3	Hh3	Hh3	Hh3	Hh3	Ar1	Ar2	Ar2	Ar1
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	2.4	2.94	2.45	15.33	2.26		13.61	14.25	13.19
2LML						18.43			
3LML									
2UML									

Repository Specimen #	UWBM 53912	UWBM 54533	UWBM 54537	UWBM 54538	UWBM 54539	UWBM 54540	UWBM 54595	UWBM 54598	UWBM 54599
Family	Equidae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae	Sciuridae
Subfamily	Equinae								
Tribe	Hipparionini								
Subtribe									
Genus	*Hipparion*								
Species	*condoni*								
Site	Bartlett Mountain	Ordnance	Ordnance	Ordnance	Ordnance	Ordnance	Ordnance	Ordnance	Ordnance
Site #	C0102	A8803	A8803	A8803	A8803	A8803	A8803	A8803	A8803
Formation	Drewsey	Alkali Canyon	Alkali Canyon	Alkali Canyon	Alkali Canyon	Alkali Canyon	Alkali Canyon	Alkali Canyon	Alkali Canyon
Age	Hh2	Hh3	Hh3	Hh3	Hh3	Hh3	Hh3	Hh3	Hh3
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	23.49								
3LPL									
4LPL									
1LML		2.55	1.8	2.9	2.68	2.6	2.67	2.85	2.29
2LML									
3LML									
2UML									

Repository Specimen #	UWBM 57555	UWBM 57583	UWBM 59241	UWBM 61529
Family	Sciuridae	Sciuridae	Equidae	Sciuridae
Subfamily	Sciurinae	Sciurinae	Equinae	Sciurinae
Tribe	Tamiini	Tamiini	Hipparionini	Tamiini
Subtribe				
Genus	*Tamias*	*Tamias*	*Nannipus*	*Tamias*
Species				
Site	Ordnance	Arlington 7	Arlington 16	McKay Reservoir
Site #	A8803	C0120	C0195	C0128
Formation	Alkali Canyon	Alkali Canyon	Alkali Canyon	McKay
Age	Hh3	Hh3	Hh3	Hh3
Source	Measurement	Measurement	Measurement	Measurement
2LPL				
3LPL				
4LPL				
1LML	1.24	0.93	12.85	1.64
2LML				
3LML				
2UML				

APPENDIX B

CHAPTER IV FOSSIL DATA

Repository – Collection in which specimen is located

Specimen # - Identification number of specimen

Taxonomy (Family, Subfamily, Tribe, Sub tribe, Genus, Species) – Specimen taxon

Site – Name of site at which specimen was found

Site # - Identification number of site

Formation – Formation in which specimen was found

Region – Biogeographic region in which the specimen was found

Subregion – Biogeographic subregion in which the specimen was found

Age – NALMA subdivision to which the specimen can be dated

Decimal – Decimal degrees latitude at which the specimen was found

Source – Source of measurement

2LPL – 2nd lower premolar length

3LPL – 3rd lower premolar length

4LPL – 4th lower premolar length

1LML – 1st lower molar length

2LML – 2nd lower molar length

3LML – 3rd lower molar length

2UML – 2nd upper molar length

Repository Specimen #	AMNH 6860	AMNH 6960	AMNH 6961	AMNH 8174	IGM 3997	IGM 3998	IGM 6412	IGM 6419	IGM 6424
Family	Canidae	Sciuridae	Sciuridae	Equidae	Equidae	Equidae	Canidae	Equidae	Equidae
Subfamily	Hesperocyoninae	Sciurinae	Sciurinae	Equinae	Equinae	Equinae	Borophaginae	Equinae	Equinae
Tribe		Basal Terrestrial Squirrels	Sciurini	Equini	Hipparionini	Hipparionini	Borophagini	Hipparionini	Equini
Subtribe							Borophagina		
Genus	*Mesocyon*	*Protospermophilus*	*Miosciurus*	*Acritohippus*	*Merychippus*	*Merychippus*	*Borophagus*	*Neohipparion*	*Astrohippus*
Species	*coryphaeus*	*vortmani*	*ballovianus*	*seversus*			*secundus*	*eurystyle*	*stockii*
Site	The Cove	Diceratherium Beds	Diceratherium Beds	Mascall	Matatlan	Matatlan	Rinconada	Rinconada	Rinconada
Site #									
Formation	John Day	John Day	John Day	Mascall	El Camarón	El Camarón			
Region	Northwest	Columbia Plateau	Columbia Plateau	Northwest	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Oaxaca	Oaxaca	Guanajuato	Guanajuato	Guanajuato
Age	Ar1	Ar1	Ar1	14.13356239			Hh4	Hh4	Hh4
Decimal	44.64	44.52	44.52	44.51	16.86	16.86	21.08	21.08	21.08
Source	Measurement	Measurement	Measurement	Downs 1956	Bravo-Cuevas & Ferrusquía-Villafranca 2006	Bravo-Cuevas & Ferrusquía-Villafranca 2006	Measurement	Measurement	Measurement
2LPL									
3LPL					17.67				
4LPL									
1LML	15.68						25.94		
2LML									
3LML						21.63			
2UML				20.7				19.12	17.11
LTRL		9.91	6.68						

Repository	IGM	IGM	IGM	IGM	IGM	IGM	IGM	IGM	IGM
Specimen #	**6425**	**6426**	**6428**	**6430**	**6431**	**6432**	**6433**	**6434**	**6456**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Dinohippus*	*Dinohippus*
Species	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*mexicanus*	*mexicanus*
Site	Rinconada	Rinconada	Rinconada	Rinconada	Rinconada	Rinconada	Rinconada	Rinconada	Rinconada
Site #									
Formation									
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Guanajuato	Guanajuato	Guanajuato	Guanajuato	Guanajuato	Guanajuato	Guanajuato	Guanajuato	Guanajuato
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	21.08	21.08	21.08	21.08	21.08	21.08	21.08	21.08	21.08
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	20.08	16.69	16.82			19.42	18.53	22.95	
2LML									
3LML									
2UML				15.36	17.44				25.58
LTRL									

Repository Specimen #	IGM 6457	IGM 6458	IGM 6677	IGM 7596	IGM 7965	IGM 8399	IGM 8400	IGM 8402	IGM 8406
Family	Equidae	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Borophaginae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Borophagini	Equini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe			Borophagina						
Genus	*Dinohippus*	*Dinohippus*	*Borophagus*	*Dinohippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species	*mexicanus*	*mexicanus*		*mexicanus*					
Site	Rinconada	El Ocote	Teocaltiche	El Ocote	Matatlan	Matatlan	Matatlan	Matatlan	Matatlan
Site #									
Formation					El Camarón	El Camarón	El Camarón	El Camarón	El Camarón
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Guanajuato	Guanajuato	Jalisco	Guanajuato	Oaxaca	Oaxaca	Oaxaca	Oaxaca	Oaxaca
Age	Hh4	Hh4	Hh4	Hh4					
Decimal	21.08	21.09	21.43	21.09	16.86	16.86	16.86	16.86	16.86
Source	Measurement	Measurement	Measurement	Measurement	Bravo-Cuevas & Ferrusquía-Villafranca 2006	Bravo-Cuevas & Ferrusquía-Villafranca 2006	Bravo-Cuevas & Ferrusquía-Villafranca 2006	Bravo-Cuevas & Ferrusquía-Villafranca 2006	Bravo-Cuevas & Ferrusquía-Villafranca 2006
2LPL									
3LPL									
4LPL									
1LML		22.43	28.56						
2LML									
3LML								19.74	21.38
2UML	23.11			23.57	20.02	19.16	20.1		
LTRL									

Repository Specimen #	**IGM 8407**	**IMNH 27930**	**IMNH 29087**	**IMNH 29088**	**JODA 333**	**JODA 1344**	**JODA 1345**	**JODA 2397**	**JODA 2413**
Family	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae	Equidae	Canidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Hesperocyoninae	Anchitheriinae	Anchitheriinae	Hesperocyoninae	Anchitheriinae
Tribe	Hipparionini	Equini	Equini	Equini					
Subtribe									
Genus	*Merychippus*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Mesocyon*	*Desmatippus*	*Desmatippus*	*Mesocyon*	*Desmatippus*
Species					*coryphaeus*	*avus*	*avus*	*coryphaeus*	*avus*
Site	Matatlan	Star Valley	Star Valley	Star Valley	Branson Creek	Mascall	Mascall	Branson Creek	Mascall
Site #		67001	67001	67001	3	4	4	3	4
Formation	El Camarón	Chalk Butte	Chalk Butte	Chalk Butte	John Day	Mascall	Mascall	John Day	Mascall
Region	Mexico	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest
Subregion	Oaxaca	Northern Great Basin	Northern Great Basin	Northern Great Basin	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau
Age		Hh2	Hh2	Hh2	Ar1	14.13356239	14.13356239	Ar1	14.13356239
Decimal	16.86	42.02	42.02	42.02	44.67	44.51	44.51	44.67	44.51
Source	Bravo-Cuevas & Ferrusquía-Villafranca 2006	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									17.38
3LPL			24.99						
4LPL						21.58			
1LML	18.12	29.3			17.22			15.15	
2LML							21.44		
3LML				33.28					
2UML									
LTRL									

Repository Specimen #	JODA 2419	JODA 2427	JODA 2435	JODA 3684	LACM 580	LACM 1736	LACM 2622	LACM 2628	LACM 2641
Family	Equidae	Equidae	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Anchitheriinae	Anchitheriinae	Anchitheriinae	Hesperocyoninae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe					Equini	Hipparionini	Hipparionini	Hipparionini	Equini
Subtribe									
Genus	*Desmatippus*	*Desmatippus*	*Desmatippus*	*Mesocyon*	*Pliohippus*	*Merychippus*	*Hipparion*	*Hipparion*	*Pliohippus*
Species	*avus*	*avus*	*avus*		*leardi*	*calamarius*	*tehonense*	*tehonense*	*leardi*
Site	Mascall	Mascall	Mascall	Logan Butte	North Tejon Hills	Tonopah	North Tejon Hills	North Tejon Hills	North Tejon Hills
Site #	4	4	4	52	CIT 104	CIT 172	CIT 104	CIT 104	CIT 302
Formation	Mascall	Mascall	Mascall	John Day	Chanac	Tonopah	Chanac	Chanac	Chanac
Region	Northwest	Northwest	Northwest	Northwest	Coast Ranges	Great Basin	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	San Joaquin Valley	Nevada	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley
Age	14.13356239	14.13356239	14.13356239	Ar1	Cl3	8.7	Cl3	Cl3	Cl3
Decimal	44.51	44.51	44.51	43.95	35.13	38.22	35.13	35.13	35.12
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL							23.84	23.89	
4LPL									
1LML		15.11		15.36					
2LML									
3LML	20.8								
2UML			15.54		29.52	21.62			30.52
LTRL									

Repository Specimen #	**LACM 2659**	**LACM 2661**	**LACM 2673**	**LACM 2674**	**LACM 2675**	**LACM 2762**	**LACM 2765**	**LACM 2805**	**LACM 3999**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Hipparionini
Subtribe									
Genus	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Hipparion*
Species	*leardi*	*leardi*	*leardi*	*leardi*	*leardi*	*leardi*	*leardi*	*leardi*	
Site	North Tejon Hills	North Tejon Hills	North Tejon Hills	North Tejon Hills	North Tejon Hills	North Tejon Hills	North Tejon Hills	North Tejon Hills	Stormys Camp
Site #	CIT 104	CIT 104	CIT 104	CIT 104	CIT 104	CIT 302	CIT 302	CIT 302	1413
Formation	Chanac	Chanac	Chanac	Chanac	Chanac	Chanac	Chanac	Chanac	Dove Spring
Region	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Great Basin
Subregion	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	Mojave Desert
Age	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3	Cl2
Decimal	35.13	35.13	35.13	35.13	35.13	35.12	35.12	35.12	35.41
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL						31.92			
3LPL									
4LPL				29.28				27.71	
1LML			28.06						
2LML									
3LML					30.07		32.39		28.04
2UML	34.06	34.59							
LTRL									

Repository Specimen #	LACM 4931	LACM 4939	LACM 5263	LACM 5264	LACM 5267	LACM 5267	LACM 5272	LACM 5273	LACM 5289
Family	Equidae	Equidae	Canidae	Canidae	Canidae	Canidae	Canidae	Canidae	Canidae
Subfamily	Equinae	Equinae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae
Tribe	Hipparionini	Hipparionini							
Subtribe									
Genus	*Scaphohippus*	*Scaphohippus*	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Mesocyon*
Species	*intermontanus*	*sumani*		*brachyops*				*brachyops*	*brachyops*
Site	Cache Peak	Cache Peak	Kew	Kew	Kew	Kew	Kew	Kew	Kew
Site #	CIT 500	CIT 501	CIT 126	CIT 126	CIT 126	CIT 126	CIT 126	CIT 126	CIT 126
Formation	Bopesta	Bopesta	Sespe	Sespe	Sespe	Sespe	Sespe	Sespe	Sespe
Region	Great Basin	Great Basin	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Mojave Desert	Mojave Desert	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges
Age	Ba1	Ba1	Ar1	Ar1	Ar1	Ar1	Ar1	Ar1	Ar1
Decimal	35.19	35.17	34.25	34.25	34.25	34.25	34.25	34.25	34.25
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML			13.94	15.2	15.07	12.83	15.42	14.33	13.24
2LML									
3LML									
2UML	22.55	21.07							
LTRL									

Repository Specimen #	LACM 5937	LACM 15618	LACM 15625	LACM 15976	LACM 16002	LACM 16016	LACM 16202	LACM 16214	LACM 16215
Family	Equidae	Equidae	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Anchitheriinae	Equinae	Equinae	Borophaginae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe		Hipparionini	Equini	Borophagini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe				Cynarctina					
Genus	*Archaeohippus*	*Scaphohippus*	*Acritohippus*	*Microtomarctus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species		*intermontanus*	*quinni*	*conferta*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*
Site	Mascall General	Cache Peak	Cache Peak	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Site #	1869	1546	CIT 502	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172
Formation	Mascall	Bopesta	Bopesta	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Region	Northwest	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin
Subregion	Columbia Plateau	Mojave Desert	Mojave Desert	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada
Age	14.13356239	Ba1		8.7	8.7	8.7	8.7	8.7	8.7
Decimal	44.51	35.17	35.17	38.22	38.22	38.22	38.22	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL					26.42				
3LPL									
4LPL									
1LML				15.27				18.14	21.12
2LML									
3LML	19.08								
2UML		20.93	18.69			23.28	22.75		
LTRL									

Repository Specimen #	LACM 16218	LACM 16219	LACM 16222	LACM 16223	LACM 16226	LACM 16230	LACM 16236	LACM 16241	LACM 16242
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*
Site	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Site #	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172
Formation	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Region	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin
Subregion	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada
Age	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
Decimal	38.22	38.22	38.22	38.22	38.22	38.22	38.22	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	23.97	19.92							
3LPL									
4LPL									
1LML			21.08	18.97			18.84	21.11	21.39
2LML									
3LML									
2UML					22.29	23.56			
LTRL									

Repository Specimen #	LACM 16243	LACM 16244	LACM 16245	LACM 16246	LACM 16247	LACM 16249	LACM 16250	LACM 16251	LACM 16252
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*
Site	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Site #	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172
Formation	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Region	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin
Subregion	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada
Age	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
Decimal	38.22	38.22	38.22	38.22	38.22	38.22	38.22	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									25.97
3LPL									
4LPL			22.32						
1LML	22.23	19.07		19.31		21.59	23.07	17.57	
2LML									
3LML					24.65				
2UML									
LTRL									

Repository Specimen #	LACM 16256	LACM 16258	LACM 16263	LACM 16265	LACM 16266	LACM 16270	LACM 16271	LACM 16274	LACM 16543
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini		Equini
Subtribe									
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Hypohippus*	*Pliohippus*
Species	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*affinis*	*leardi*
Site	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	North Tejon Hills
Site #	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 302
Formation	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Chanac
Region	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Coast Ranges
Subregion	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	San Joaquin Valley
Age	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	Cl3
Decimal	38.22	38.22	38.22	38.22	38.22	38.22	38.22	38.22	35.12
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL				23.15	23.73				
3LPL									
4LPL	22.84								29.51
1LML		18.19				19.09	20.6		
2LML									
3LML			26.95						
2UML								22.6	
LTRL									

Repository Specimen #	**LACM 16545**	**LACM 33847**	**LACM 35386**	**LACM 35388**	**LACM 38751**	**LACM 40208**	**LACM 42810**	**LACM 60496**	**LACM 62557**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Pliohippus*	*Scaphohippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Hipparion*	*Neohipparion*
Species	*leardi*	*sumani*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*forcei*	*floresi*
Site	North Tejon Hills	Barstow Syncline	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Powerline Road	Yepomera (Rincon)
Site #	CIT 104	CIT 1168	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	3581	CIT 275
Formation	Chanac	Barstow	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Dove Spring	Salada
Region	Coast Ranges	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Mexico
Subregion	San Joaquin Valley	Mojave Desert	Nevada	Nevada	Nevada	Nevada	Nevada	Mojave Desert	Chihuahua
Age	Cl3	Ba1	8.7	8.7	8.7	8.7	8.7	Cl3	Hh4
Decimal	35.13	35.03	38.22	38.22	38.22	38.22	38.22	35.39	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	28.67		23.5						
3LPL								27.04	21.86
4LPL									
1LML				15.87		21.1			
2LML									
3LML					26.08		25.79		
2UML		20.1							
LTRL									

Repository Specimen #	LACM 62558	LACM 62559	LACM 62560	LACM 62561	LACM 62606	LACM 62607	LACM 62608	LACM 62613	LACM 62616
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Astrohippus*	*Dinohippus*
Species	*floresi*	*floresi*	*floresi*	*floresi*	*mexicanus*	*mexicanus*	*mexicanus*	*stockii*	*mexicanus*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL	21.48								
1LML		19.66	18.49						
2LML				25.7					
3LML									
2UML					21.43	21.18	26.84	20.36	20.07
LTRL									

Repository Specimen #	**LACM 62617**	**LACM 62620**	**LACM 62621**	**LACM 62622**	**LACM 62623**	**LACM 62624**	**LACM 62627**	**LACM 62630**	**LACM 62631**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*
Species	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL								24.92	
4LPL							24.69		
1LML	24.55	25.47	26.9	23.54	23.58	22.79			22.31
2LML									
3LML									
2UML									
LTRL									

Repository Specimen #	LACM 62632	LACM 62633	LACM 62634	LACM 62635	LACM 62636	LACM 62637	LACM 62967	LACM 62968	LACM 63317
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Astrohippus*
Species	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*stockii*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL					25.96				
3LPL									
4LPL									22.5
1LML	27.6		21.96				23.62	24.9	
2LML		23.6				20.79			
3LML				28.79					
2UML									
LTRL									

Repository Specimen #	**LACM 63321**	**LACM 63349**	**LACM 74131**	**LACM 74139**	**LACM 74140**	**LACM 80335**	**LACM 80345**	**LACM 80346**	**LACM 80355**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*
Species			*arellanoi*	*arellanoi*	*arellanoi*	*arellanoi*	*arellanoi*	*arellanoi*	*arellanoi*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 277	CIT 277	CIT 277	CIT 286	CIT 286	CIT 286	CIT 286
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	17.16	18.44		18.28			17.73	19.24	
2LML									
3LML					24.13				27.59
2UML			20.12			19.51			
LTRL									

Repository Specimen #	**LACM 81435**	**LACM 95571**	**LACM 97162**	**LACM 97182**	**LACM 97183**	**LACM 123497**	**LACM 134493**	**LACM 138075**	**LACM 138112**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Equini	Equini	Equini
Subtribe									
Genus	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Neohipparion*	*Acritohippus*	*Acritohippus*	*Acritohippus*
Species		*arellanoi*				*arellanoi*	*quinni*	*quinni*	*quinni*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Upper Dry Canyon	Upper Dry Canyon	Upper Dry Canyon
Site #	CIT 289	CIT 295	CIT 299	CIT 435	CIT 435	CIT 286	5902	6235	5900
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Caliente	Caliente	Caliente
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Transverse Ranges	Transverse Ranges	Transverse Ranges
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4			
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	34.77	34.77	34.77
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML			25.36	19.72		19.94	19.5	21.8	18.69
2LML					21.15				
3LML									
2UML	20.19	19.13							
LTRL									

Repository Specimen #	LACM 148908	LACM 148910	LACM 151054	LACM 151061	LACM CIT 104	LACM CIT 1045	LACM CIT 1046	LACM CIT 1053	LACM CIT 1055
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Anchitheriinae	Anchitheriinae	Equinae	Equinae
Tribe	Equini	Equini	Hipparionini	Hipparionini				Equini	Equini
Subtribe									
Genus	*Pliohippus*	*Pliohippus*	*Merychippus*	*Merychippus*	*Hypohippus*	*Desmatippus*	*Desmatippus*	*Acritohippus*	*Acritohippus*
Species			*californicus*	*californicus*	*affinis*	*avus*	*avus*	*isonesus*	*isonesus*
Site	Powerline Road	Between Basalts	Coalinga North	Coalinga Merychippus Zone	Tonopah	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek
Site #	5686	5697	CIT 108	CIT 129	CIT 172	CIT 44	CIT 44	CIT 44	CIT 44
Formation	Dove Spring	Dove Spring	Temblor	Temblor	Tonopah	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek
Region	Great Basin	Great Basin	Coast Ranges	Coast Ranges	Great Basin	Northwest	Northwest	Northwest	Northwest
Subregion	Mojave Desert	Mojave Desert	San Joaquin Valley	San Joaquin Valley	Nevada	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau
Age	Cl3	Cl2	17.3	17.3	8.7	14.13356239	14.13356239	14.13356239	14.13356239
Decimal	35.39	35.41	36.32	36.32	38.22	43.44	43.44	43.44	43.44
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL		22.67	20.51	19.75		19.25			
3LPL									
4LPL									
1LML									19.92
2LML									
3LML	30.33						20.67		
2UML					28.72			19.79	
LTRL									

Repository Specimen #	LACM CIT 1056	LACM CIT 1057	LACM CIT 1058	LACM CIT 1059	LACM CIT 1123	LACM CIT 1124	LACM CIT 1152	LACM CIT 1229	LACM CIT 1232
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae	Canidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Borophaginae	Borophaginae
Tribe	Equini	Equini	Equini	Equini	Hipparionini	Hipparionini		Borophagini	Borophagini
Subtribe								Cynarctina	Cynarctina
Genus	*Acritohippus*	*Acritohippus*	*Acritohippus*	*Acritohippus*	*Merychippus*	*Merychippus*	*Desmatippus*	*Microtomarctus*	*Microtomarctus*
Species	*isonesus*	*isonesus*	*isonesus*	*isonesus*	*brevidontus*	*brevidontus*	*avus*	*conferta*	*conferta*
Site	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Coalinga North	Tonopah	Tonopah
Site #	CIT 44	CIT 44	CIT 44	CIT 44	CIT 44	CIT 44	CIT 108		CIT 172
Formation	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Sucker Creek	Temblor	Siebert	Tonopah
Region	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Coast Ranges	Great Basin	Great Basin
Subregion	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	San Joaquin Valley	Nevada	Nevada
Age	14.13356239	14.13356239	14.13356239	14.13356239	14.13356239	14.13356239	17.3	8.7	8.7
Decimal	43.44	43.44	43.44	43.44	43.44	43.44	36.32	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Henshaw 1942	Measurement
2LPL		18.39		19.41		19.89			
3LPL									
4LPL									
1LML								15	16.06
2LML	19.17								
3LML			23.84				20.63		
2UML					19.37				
LTRL									

Repository Specimen #	LACM CIT 1238	LACM CIT 1239	LACM CIT 1311	LACM CIT 1312	LACM CIT 1313	LACM CIT 1314	LACM CIT 1346	LACM CIT 1401	LACM CIT 1404
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae	Equidae
Subfamily	Anchitheriinae	Anchitheriinae	Equinae	Equinae	Equinae	Equinae	Hesperocyoninae	Anchitheriinae	Anchitheriinae
Tribe			Hipparionini	Hipparionini	Hipparionini	Hipparionini			
Subtribe									
Genus	*Hypohippus*	*Hypohippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Mesocyon*	*Hypohippus*	*Hypohippus*
Species	*affinis*	*affinis*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*brachyops*	*affinis*	*affinis*
Site	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Kew	Tonopah	Tonopah
Site #	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 126	CIT 172	
Formation	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Sespe	Tonopah	Siebert
Region	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Coast Ranges	Great Basin	Great Basin
Subregion	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Transverse Ranges	Nevada	Nevada
Age	8.7	8.7	8.7	8.7	8.7	8.7	Ar1	8.7	8.7
Decimal	38.22	38.22	38.22	38.22	38.22	38.22	34.25	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Henshaw 1942
2LPL									
3LPL									
4LPL									
1LML					18.27	21.68	17.13		
2LML									
3LML									
2UML	25.17	28.61	21.4	20.14				25.01	28.8
LTRL									

Repository Specimen #	LACM CIT 1419	LACM CIT 1769	LACM CIT 1770	LACM CIT 1819	LACM CIT 1822	LACM CIT 1823	LACM CIT 1824	LACM CIT 1880	LACM CIT 1881
Family	Equidae	Equidae	Equidae	Canidae	Canidae	Canidae	Canidae	Equidae	Equidae
Subfamily	Equinae	Anchitheriinae	Equinae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Anchitheriinae	Anchitheriinae
Tribe	Hipparionini		Hipparionini						
Subtribe									
Genus	*Merychippus*	*Hypohippus*	*Merychippus*	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Hypohippus*	*Hypohippus*
Species	*brevidontus*	*osborni*	*brevidontus*	*brachyops*	*brachyops*		*brachyops*	*affinis*	*affinis*
Site	Coalinga North	Sucker Creek	Sucker Creek	Kew	Kew	Kew	Kew	Tonopah	Tonopah
Site #	CIT 108	CIT 44	CIT 58	CIT 126	CIT 126	CIT 126	CIT 126	CIT 172	CIT 172
Formation	Temblor	Sucker Creek	Sucker Creek	Sespe	Sespe	Sespe	Sespe	Tonopah	Tonopah
Region	Coast Ranges	Northwest	Northwest	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Great Basin	Great Basin
Subregion	San Joaquin Valley	Columbia Plateau	Columbia Plateau	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Nevada	Nevada
Age	17.3	14.13356239	14.13356239	Ar1	Ar1	Ar1	Ar1	8.7	8.7
Decimal	36.32	43.44	43.44	34.25	34.25	34.25	34.25	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML				13.39	14.52	15.59	13.49	24.37	23.52
2LML									
3LML		23.03							
2UML	19.62		18.91						
LTRL									

Repository Specimen #	LACM CIT 2620	LACM CIT 2637	LACM CIT 2834	LACM CIT 2839	LACM CIT 2840	LACM CIT 2841	LACM CIT 2842	LACM CIT 2847	LACM CIT 2860
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Anchitheriinae
Tribe	Hipparionini	Equini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini		
Subtribe									
Genus	*Hipparion*	*Pliohippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Hypohippus*	*Hypohippus*
Species	*forcei*	*leardi*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*affinis*	*affinis*
Site	North Tejon Hills	North Tejon Hills	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Site #	CIT 104	CIT 302	CIT 172	CIT 172	CIT 172		CIT 172		CIT 172
Formation	Chanac	Chanac	Tonopah	Tonopah	Tonopah	Siebert	Tonopah	Siebert	Tonopah
Region	Coast Ranges	Coast Ranges	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin
Subregion	San Joaquin Valley	San Joaquin Valley	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada
Age	Cl3	Cl3	8.7	8.7	8.7	8.7	8.7	8.7	8.7
Decimal	35.13	35.12	38.22	38.22	38.22	38.22	38.22	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Henshaw 1942	Measurement	Henshaw 1942	Measurement
2LPL								23.6	
3LPL									
4LPL									
1LML			21.3				20.84		
2LML									
3LML									
2UML	23.13	26.44		21.41	22.91	21.2			27.4
LTRL									

Repository Specimen #	**LACM CIT 2929**	**LACM CIT 2930**	**LACM CIT 3056**	**LACM CIT 3057**	**LACM CIT 3063**	**LACM CIT 3091**	**LACM CIT 3092**	**LACM CIT 3329**	**LACM CIT 3338**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini		Equini	Equini	Hipparionini	Hipparionini
Subtribe									
Genus	*Acritohippus*	*Acritohippus*	*Acritohippus*	*Acritohippus*	*Hypohippus*	*Acritohippus*	*Acritohippus*	*Neohipparion*	*Neohipparion*
Species	*seversus*	*seversus*	*isonesus*	*isonesus*	*osborni*	*isonesus*	*isonesus*	*floresi*	*floresi*
Site	Gateway	Gateway	Sucker Creek	Beatty Buttes	Beatty Buttes	Sucker Creek	Sucker Creek	Yepomera (Rincon)	Yepomera (Rincon)
Site #		CIT 368		CIT 371	CIT 371			CIT 281	CIT 281
Formation	Mascall	Mascall	Sucker Creek	Beatty Butte	Beatty Butte	Sucker Creek	Sucker Creek	Salada	Salada
Region	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Mexico	Mexico
Subregion	Columbia Plateau	Columbia Plateau	Columbia Plateau	Northern Great Basin	Northern Great Basin	Columbia Plateau	Columbia Plateau	Chihuahua	Chihuahua
Age	14.13356239	14.13356239	14.13356239			14.13356239	14.13356239	Hh4	Hh4
Decimal	44.76	44.76	43.44	42.45	42.45	43.44	43.44	28.63	28.63
Source	Downs 1956	Measurement	Wallace 1946	Measurement	Measurement	Wallace 1946	Wallace 1946	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML									18.49
2LML									
3LML			25	24.15	24.77				
2UML	15.3	18.34				21	20.8	19.68	
LTRL									

Repository Specimen #	LACM CIT 3578	LACM CIT 3625	LACM CIT 3626	LACM CIT 3627	LACM CIT 3628	LACM CIT 3629	LACM CIT 3630	LACM CIT 3631	LACM CIT 3632
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Hipparionini	Equini	Equini
Subtribe									
Genus	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Neohipparion*	*Astrohippus*	*Astrohippus*
Species	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*arellanoi*	*stockii*	*stockii*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML		18.26	17.87	19.41	20.9	17.3	18.6	16.68	15.94
2LML									
3LML									
2UML	17.05								
LTRL									

Repository Specimen #	**LACM CIT 3633**	**LACM CIT 3634**	**LACM CIT 3637**	**LACM CIT 3638**	**LACM CIT 3639**	**LACM CIT 3640**	**LACM CIT 3641**	**LACM CIT 3642**	**LACM CIT 3643**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*
Species	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	18.82	17.79	17.06		20.11	20.65	16.54	20.27	15.83
2LML				16.15					
3LML									
2UML									
LTRL									

Repository Specimen #	LACM CIT 3645	LACM CIT 3647	LACM CIT 3648	LACM CIT 3650	LACM CIT 3651	LACM CIT 3652	LACM CIT 3653	LACM CIT 3654	LACM CIT 3655
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*
Species	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	18.11	17.12	19.26	16.28	18.75	16.58	20.1	16.61	17.74
2LML									
3LML									
2UML									
LTRL									

Repository Specimen #	LACM CIT 3656	LACM CIT 3657	LACM CIT 3658	LACM CIT 3659	LACM CIT 3660	LACM CIT 3661	LACM CIT 3662	LACM CIT 3663	LACM CIT 3664
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*
Species	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*	*stockii*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	17.51	18.48	19.25	15.96	16.45	19.63	17.58	17.67	20.94
2LML									
3LML									
2UML									
LTRL									

Repository Specimen #	**LACM CIT 3665**	**LACM CIT 3666**	**LACM CIT 3667**	**LACM CIT 3679**	**LACM CIT 3698**	**LACM CIT 3699**	**LACM CIT 3701**	**LACM CIT 3704**	**LACM CIT 3705**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Astrohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*
Species	*stockii*	*stockii*	*stockii*	*stockii*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	18.9	19.07	20.6	12.87	22.72	24.57		24.36	
2LML									
3LML									
2UML							24.99		26.21
LTRL									

Repository Specimen #	**LACM CIT 3711**	**LACM CIT 3713**	**LACM CIT 3714**	**LACM CIT 3715**	**LACM CIT 3717**	**LACM CIT 3718**	**LACM CIT 3747**	**LACM CIT 3748**	**LACM CIT 3750**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*
Species	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*	*mexicanus*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)
Site #	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275	CIT 275
Formation	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada	Salada
Region	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Chihuahua
Age	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63	28.63
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	23.76	22.96	22.87	21.79		20.79			24.06
2LML									
3LML									
2UML					23.81		22.01	22.32	
LTRL									

Repository Specimen #	**LACM CIT 3839**	**LACM CIT 3888**	**LACM CIT 3889**	**LACM CIT 3890**	**LACM CIT 4090**	**LACM CIT 4095**	**LACM CIT 4103**	**LACM CIT 4104**	**LACM CIT 437**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Equini	Equini	Equini	Hipparionini		Hipparionini	Hipparionini	Equini
Subtribe									
Genus	*Neohipparion*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Merychippus*	*Archaeohippus*	*Merychippus*	*Merychippus*	*Acritohippus*
Species	*floresi*	*mexicanus*	*mexicanus*	*mexicanus*	*brevidontus*	*ultimus*	*calamarius*	*calamarius*	*isonesus*
Site	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Yepomera (Rincon)	Virgin Valley	Gateway	Tonopah	Tonopah	Sucker Creek
Site #	CIT 281	CIT 275	CIT 275	CIT 275	CIT 114	CIT 368	CIT 172	CIT 172	CIT 44
Formation	Salada	Salada	Salada	Salada	Virgin Valley	Mascall	Tonopah	Tonopah	Sucker Creek
Region	Mexico	Mexico	Mexico	Mexico	Northwest	Northwest	Great Basin	Great Basin	Northwest
Subregion	Chihuahua	Chihuahua	Chihuahua	Chihuahua	Northern Great Basin	Columbia Plateau	Nevada	Nevada	Columbia Plateau
Age	Hh4	Hh4	Hh4	Hh4		14.13356239	8.7	8.7	14.13356239
Decimal	28.63	28.63	28.63	28.63	41.80	44.76	38.22	38.22	43.44
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	20.67	23.28	21.78	23.5	16.72				
2LML									
3LML						14.91			
2UML							21.78	21.81	22.11
LTRL									

Repository Specimen #	LACM CIT 467	LACM CIT 488	LACM CIT 489	LACM CIT 4916	LACM CIT 493	LACM CIT 4969	LACM CIT 4970	LACM CIT 4971	LACM CIT 4972
Family	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Hesperocyoninae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe		Hipparionini	Hipparionini	Equini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Mesocyon*	*Merychippus*	*Merychippus*	*Acritohippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species	*brachyops*	*californicus*	*californicus*	*seversus*	*californicus*	*calamarius*	*calamarius*	*calamarius*	*calamarius*
Site	Kew	Coalinga North	Coalinga North	Gateway	Coalinga Merychippus Zone	Tonopah	Tonopah	Tonopah	Tonopah
Site #	CIT 126	CIT 108	CIT 108	CIT 368	CIT 129	CIT 172	CIT 172	CIT 172	CIT 172
Formation	Sespe	Temblor	Temblor	Mascall	Temblor	Tonopah	Tonopah	Tonopah	Tonopah
Region	Coast Ranges	Coast Ranges	Coast Ranges	Northwest	Coast Ranges	Great Basin	Great Basin	Great Basin	Great Basin
Subregion	Transverse Ranges	San Joaquin Valley	San Joaquin Valley	Columbia Plateau	San Joaquin Valley	Nevada	Nevada	Nevada	Nevada
Age	Ar1	17.3	17.3	14.13356239	17.3	8.7	8.7	8.7	8.7
Decimal	34.25	36.32	36.32	44.76	36.32	38.22	38.22	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	12.94	17.02	16.65		16.54	17.72	21.33	19.78	22.94
2LML									
3LML									
2UML				19.48					
LTRL									

Repository Specimen #	LACM CIT 4973	LACM CIT 4977	LACM CIT 4978	LACM CIT 4982	LACM CIT 4986	LACM CIT 5011	LACM CIT 5081	LACM CIT 5089	LACM CIT 532
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini		Hipparionini	Hipparionini	Equini
Subtribe									
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Hypohippus*	*Neohipparion*	*Neohipparion*	*Acritohippus*
Species	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*		*floresi*	*arellanoi*	*seversus*
Site	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Beatty Buttes	Yepomera (Rincon)	Yepomera (Rincon)	Mascall Type
Site #	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 371	CIT 275	CIT 289	CIT 532
Formation	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Beatty Butte	Salada	Salada	Mascall
Region	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Northwest	Mexico	Mexico	Northwest
Subregion	Nevada	Nevada	Nevada	Nevada	Nevada	Northern Great Basin	Chihuahua	Chihuahua	Columbia Plateau
Age	8.7	8.7	8.7	8.7	8.7		Hh4	Hh4	14.13356239
Decimal	38.22	38.22	38.22	38.22	38.22	42.45	28.63	28.63	44.51
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL				22.27					
3LPL									
4LPL									
1LML						21.93		21.13	
2LML									
3LML					27.08				
2UML	21.78	22.91	22.16				24.13		19.26
LTRL									

Repository Specimen #	LACM CIT 651	LACM CIT 654	LACM CIT 657	LACM CIT 659	LACM CIT 661	LACM CIT 662	LACM CIT 665	LACM CIT 667	LACM CIT 668
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*
Species	*californicus*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*
Site	Coalinga Merychippus Zone	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Site #	CIT 129	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172
Formation	Temblor	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Region	Coast Ranges	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin
Subregion	San Joaquin Valley	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada
Age	17.3	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
Decimal	36.32	38.22	38.22	38.22	38.22	38.22	38.22	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML	18.36			18.86				20.93	
2LML									
3LML							25.18		
2UML		20.98	22.15		23.14	19.58			21.48
LTRL									

Repository	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**	**LACM**
Specimen #	**CIT 669**	**CIT 671**	**CIT 672**	**CIT 673**	**CIT 674**	**CIT 675**	**CIT 676**	**CIT 678**	**CIT 680**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	
Subtribe									
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Hypohippus*
Species	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*calamarius*	*affinis*
Site	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Site #	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172	CIT 172
Formation	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah	Tonopah
Region	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin
Subregion	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada	Nevada
Age	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
Decimal	38.22	38.22	38.22	38.22	38.22	38.22	38.22	38.22	38.22
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									22.81
4LPL									
1LML		19.25	19.32	19.95		19.73	16.97	21.56	
2LML									
3LML									
2UML	22.32				23.11				
LTRL									

Repository Specimen #	LACM CIT 681	LACM CIT 884	LACM CIT 886	LACM CIT 975	RAM 7146	RAM 7361	SDNHM 28595	SDNHM 28595	SDNHM 29092
Family	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae	Canidae	Canidae	Sciuridae
Subfamily	Equinae	Anchitheriinae	Anchitheriinae	Equinae	Borophaginae	Equinae	Hesperocyoninae	Hesperocyoninae	Sciurinae
Tribe	Hipparionini			Hipparionini	Borophagini	Hipparionini			Sciurini
Subtribe					Cynarctina				
Genus	*Merychippus*	*Archaeohippus*	*Hypohippus*	*Merychippus*	*Microtomarctus*	*Scaphohippus*	*Mesocyon*	*Mesocyon*	*Protosciurus*
Species	*calamarius*	*mourningi*		*calamarius*		*sumani*	*coryphaeus*	*coryphaeus*	
Site	Tonopah	Coalinga Merychippus Zone	Coalinga Merychippus Zone	Tonopah	Webb G	Webb D	EastLake Shores	EastLake Shores	EastLake Shores
Site #	CIT 172	CIT 129	CIT 129	CIT 172	V94063	V94060	3280	3280	3280
Formation	Tonopah	Temblor	Temblor	Tonopah	Barstow	Barstow	Otay	Otay	Otay
Region	Great Basin	Coast Ranges	Coast Ranges	Great Basin	Great Basin	Great Basin	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges
Subregion	Nevada	San Joaquin Valley	San Joaquin Valley	Nevada	Mojave Desert	Mojave Desert	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges
Age	8.7	17.3	17.3	8.7		Ba1	Ar1	Ar1	Ar1
Decimal	38.22	36.32	36.32	38.22	35.03	35.03	32.65	32.65	32.65
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL			19.74						
3LPL									
4LPL									
1LML					22.76		16.98	16.98	
2LML									
3LML		14.11							
2UML	21.97			21.82		25.07			
LTRL									6.31

Repository Specimen #	SDNHM 42851	SDNHM 42851	SDNHM 88919	SDNHM 88919	SDNHM 104317	SDNHM 104317	SDSM 10607	SDSM 16742	SDSM 16744
Family	Canidae	Canidae	Canidae	Canidae	Canidae	Canidae	Equidae	Equidae	Equidae
Subfamily	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Hesperocyoninae	Equinae	Equinae	Equinae
Tribe							Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Mesocyon*	*Hipparion*	*Hipparion*	*Hipparion*
Species	*coryphaeus*	*coryphaeus*					*condoni*	*condoni*	*condoni*
Site	Salt Creek 1	Salt Creek 1	EastLake Business Center, Site 35	EastLake Business Center, Site 35	McMillin Rolling Hills Ranch, Neigh. 9-12	McMillin Rolling Hills Ranch, Neigh. 9-12	Buena	Toppenish-Goldendale	Buena
Site #	3566	3566	3331	3331	5611	5611	6414	6415	6414
Formation	Otay	Otay	Otay	Otay	Otay	Otay	Ellensburg	Ellensburg	Ellensburg
Region	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Northwest	Northwest	Northwest
Subregion	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Columbia Plateau	Columbia Plateau	Columbia Plateau
Age	Ar1	Ar1	Ar1	Ar1	Ar1	Ar1	Cl3	Cl3	Cl3
Decimal	32.65	32.65	32.65	32.65	32.65	32.65	46.34	46.34	46.34
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									23.82
3LPL									
4LPL									
1LML	17.05	17.05	16.61	16.61	16.68	16.68	23.28		
2LML								23.54	
3LML									
2UML									
LTRL									

Repository Specimen #	**SDSM 16753**	**SDSM 16757**	**SDSM 66313**	**UCMP 1178**	**UCMP 1618**	**UCMP 1625**	**UCMP 1718**	**UCMP 2028**	**UCMP 10665**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Equini	Equini	Equini	Equini	Equini	
Subtribe									
Genus	*Hipparion*	*Hipparion*	*Hipparion*	*Acritohippus*	*Acritohippus*	*Acritohippus*	*Acritohippus*	*Acritohippus*	*Hypohippus*
Species	*condoni*	*condoni*		*seversus*	*seversus*	*seversus*	*isonesus*	*seversus*	*osborni*
Site	Moxee	Buena	Horse Locality	Mascall General	Mascall Misc. 2	Mascall Misc. 2	Schneider Ranch	Schneider Ranch	Virgin Valley
Site #	6425	6414	6367	67153	884	884	903	903	1065
Formation	Ellensburg	Ellensburg	Ellensburg	Mascall	Mascall	Mascall	Mascall	Mascall	Virgin Valley
Region	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest
Subregion	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Northern Great Basin
Age	Cl3	Cl3	Cl3	14.13356239	14.13356239	14.13356239	14.13356239	14.13356239	
Decimal	46.34	46.34	46.34	44.51	44.51	44.51	44.49	44.49	41.65
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL					19.14				24.6
3LPL									
4LPL			24.22						
1LML		19.72		15.76					
2LML									
3LML	21.71					18.26	21.05	20.72	
2UML									
LTRL									

Repository Specimen #	UCMP 12587	UCMP 19460	UCMP 19763	UCMP 19764	UCMP 21214	UCMP 21249	UCMP 21325	UCMP 21386	UCMP 21398
Family	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Anchitheriinae	Borophaginae	Anchitheriinae	Anchitheriinae	Anchitheriinae	Equinae	Equinae	Equinae	Equinae
Tribe		Borophagini				Hipparionini	Hipparionini	Equini	Hipparionini
Subtribe		Cynarctina							
Genus	*Hypohippus*	*Tephrocyon*	*Hypohippus*	*Archaeohippus*	*Hypohippus*	*Merychippus*	*Merychippus*	*Acritohippus*	*Scaphohippus*
Species	*osborni*	*rurestris*	*osborni*	*mourningi*		*californicus*	*californicus*	*stylodontus*	*intermontanus*
Site	Virgin Valley 4	Rodent Hill	Stewart Springs	Coon Canyon	Coon Canyon	Coalinga North	Merychippus Zone 1	Coon Canyon	Coon Canyon
Site #	1085	1399	2027	2058	2057	2124	2124	2058	2057
Formation	Virgin Valley	Barstow	Esmeralda	Barstow	Barstow	Temblor	Temblor	Barstow	Barstow
Region	Northwest	Great Basin	Great Basin	Great Basin	Great Basin	Coast Ranges	Coast Ranges	Great Basin	Great Basin
Subregion	Northern Great Basin	Mojave Desert	Nevada	Mojave Desert	Mojave Desert	San Joaquin Valley	San Joaquin Valley	Mojave Desert	Mojave Desert
Age		Ba2	8.7			17.3	17.3		Ba1
Decimal	41.86	35.05	38.59	35.03	35.03	36.32	36.32	35.03	35.03
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL							19.42		
3LPL									
4LPL									
1LML	20.17	17.82		13.42					21.36
2LML			19.42			20.9			
3LML									
2UML					24.1			21.32	
LTRL									

Repository Specimen #	UCMP 22351	UCMP 22388	UCMP 22391	UCMP 23088	UCMP 23098	UCMP 23209	UCMP 23214	UCMP 23287	UCMP 23307
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Equini
Subtribe									
Genus	*Hipparion*	*Pliohippus*	*Pliohippus*	*Acritohippus*	*Acritohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*
Species	*anthonyi*	*spectans*	*spectans*	*seversus*	*seversus*	*leidyanus*	*leidyanus*	*leidyanus*	*leidyanus*
Site	Ironside	Rattlesnake 11	Rattlesnake 11	Mascall 5	Mascall 1	Mt. Eden General	Mt. Eden General	Mt. Eden General	Mt. Eden General
Site #	3037	3060	3060	3059	3043	6573	6573	6573	6573
Formation	Juntura	Rattlesnake	Rattlesnake	Mascall	Mascall	Mt. Eden	Mt. Eden	Mt. Eden	Mt. Eden
Region	Northwest	Northwest	Northwest	Northwest	Northwest	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges
Subregion	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges	Peninsular Ranges
Age	Cl3	Hh2	Hh2	14.13356239	14.13356239	Hh4	Hh4	Hh4	Hh4
Decimal	44.31	44.52	44.52	44.51	44.51	33.89	33.89	33.89	33.89
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	27.75				19.46	29.14	31.03		23.34
3LPL									
4LPL									
1LML		24.72							
2LML									
3LML								26.99	
2UML			24.72	20.23					
LTRL									

Repository Specimen #	**UCMP 23326**	**UCMP 23510**	**UCMP 29778**	**UCMP 29956**	**UCMP 29962**	**UCMP 29963**	**UCMP 32753**	**UCMP 33539**	**UCMP 33542**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Equini	Equini	Equini	Equini	Hipparionini	Hipparionini
Subtribe									
Genus	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Acritohippus*	*Hipparion*	*Hipparion*
Species	*leidyanus*	*leidyanus*	*leidyanus*				*seversus*		
Site	Mt. Eden	Mt. Eden	Warren Syncline 2	Rattlesnake 9	Rattlesnake 11	Rattlesnake 11	Gateway	Black Hawk Ranch	Black Hawk Ranch
Site #	3269	3269	2503	3057	3060	3060	3472	3310	3310
Formation	Mt. Eden	Mt. Eden	Horned Toad	Rattlesnake	Rattlesnake	Rattlesnake	Mascall	Green Valley	Green Valley
Region	Peninsular Ranges	Peninsular Ranges	Great Basin	Northwest	Northwest	Northwest	Northwest	Coast Ranges	Coast Ranges
Subregion	Peninsular Ranges	Peninsular Ranges	Mojave Desert	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Bay Area	Bay Area
Age	Hh4	Hh4	Hh4	Hh2	Hh2	Hh2	14.13356239	Cl3	Cl3
Decimal	33.89	33.89	35.09	44.48	44.52	44.52	44.76	37.82	37.82
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	27.26	26.38	29.05		31.61				
3LPL									
4LPL						29.31			
1LML									
2LML									
3LML				27.62					28.47
2UML							18.19	20.61	
LTRL									

Repository Specimen #	**UCMP 34088**	**UCMP 34089**	**UCMP 34090**	**UCMP 34091**	**UCMP 34102**	**UCMP 34109**	**UCMP 34308**	**UCMP 34511**	**UCMP 34597**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Equini	Hipparionini	Equini
Subtribe									
Genus	*Hipparion*	*Hipparion*	*Hipparion*	*Hipparion*	*Hipparion*	*Hipparion*	*Pliohippus*	*Hipparion*	*Pliohippus*
Species									*fairbanksi*
Site	Black Hawk Ranch	Black Hawk Ranch	Black Hawk Ranch	Black Hawk Ranch	Black Hawk Ranch	Black Hawk Ranch	Martin Creek 2	Black Hawk Ranch	Black Hawk Ranch
Site #	3310	3310	3310	3310	3310	3310	3905	3310	3310
Formation	Green Valley	Green Valley	Green Valley	Green Valley	Green Valley	Green Valley	San Pablo	Green Valley	Green Valley
Region	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area
Age	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3	Cl2	Cl3	Cl3
Decimal	37.82	37.82	37.82	37.82	37.82	37.82	37.55	37.82	37.82
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	25.98	24.9	24.56	22.01					32.03
3LPL									
4LPL									
1LML									
2LML							24.5		
3LML					23.97	26.43			
2UML								19.52	
LTRL									

Repository Specimen #	**UCMP 34598**	**UCMP 34614**	**UCMP 35476**	**UCMP 35867**	**UCMP 35871**	**UCMP 35969**	**UCMP 38660**	**UCMP 38677**	**UCMP 38799**
Family	Equidae	Sciuridae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Sciurinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Marmotini	Equini	Equini	Equini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Hipparion*	*Spermophilus*	*Pliohippus*	*Pliohippus*	*Pliohippus*	*Hipparion*	*Neohipparion*	*Neohipparion*	*Hipparion*
Species	*forcei*								
Site	Black Hawk Ranch	Black Hawk Ranch	Stormy's Camp 1	Ingram Creek 8	Ingram Creek 8	Ingram Creek 10	Brady Pocket 1	Brady Pocket 1	Brady Pocket 1
Site #	3310	3310	2729	3952	3952	3954	4845	4845	4845
Formation	Green Valley	Green Valley	Dove Spring	San Pablo	San Pablo	San Pablo	Truckee	Truckee	Truckee
Region	Coast Ranges	Coast Ranges	Great Basin	Coast Ranges	Coast Ranges	Coast Ranges	Great Basin	Great Basin	Great Basin
Subregion	Bay Area	Bay Area	Mojave Desert	Bay Area	Bay Area	Bay Area	Nevada	Nevada	Nevada
Age	Cl3	Cl3	Cl2	Cl2	Cl2	Cl2	Cl3	Cl3	Cl3
Decimal	37.82	37.82	35.41	37.54	37.54	37.53	39.93	39.93	39.93
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL							22.77	30.87	22.66
3LPL									
4LPL									
1LML									
2LML									
3LML	25.44				34.22				
2UML			29.73	30.29		20.38			
LTRL		9							

Repository Specimen #	**UCMP 39095**	**UCMP 39505**	**UCMP 39663**	**UCMP 39880**	**UCMP 40315**	**UCMP 45135**	**UCMP 45136**	**UCMP 45136**	**UCMP 45292**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Anchitheriinae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Equini	Hipparionini	Equini		Equini	Hipparionini	Hipparionini	Hipparionini	Equini
Subtribe									
Genus	*Acritohippus*	*Hipparion*	*Pliohippus*	*Archaeohippus*	*Acritohippus*	*Hipparion*	*Hipparion*	*Hipparion*	*Pliohippus*
Species	*seversus*			*ultimus*	*seversus*				
Site	Mascall 16	Newton	Orinda Schoolhouse	Crooked River	Crooked River 2	Ingram Creek 11	Ingram Creek 1	Ingram Creek 1	Siesta Valley 2
Site #	4830	5006	5017		4949	5512	3616	3616	3652
Formation	Mascall	San Pablo	Mulholland	Mascall	Mascall	San Pablo	San Pablo	San Pablo	Siesta
Region	Northwest	Coast Ranges	Coast Ranges	Northwest	Northwest	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Columbia Plateau	Bay Area	Bay Area	Columbia Plateau	Columbia Plateau	Bay Area	Bay Area	Bay Area	Bay Area
Age	14.13356239	Cl2	Hh2	14.13356239	14.13356239	Cl2	Cl2	Cl2	Cl3
Decimal	44.51	37.50	37.83	44.05	44.08	37.54	37.54	37.54	37.87
Source	Measurement	Measurement	Measurement	Downs 1956	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL		27.45					20.92		
3LPL									
4LPL									
1LML	19.01								24.26
2LML									
3LML			31.18	13.7	22.11	25.15		21.41	
2UML									
LTRL									

Repository Specimen #	**UCMP 45305**	**UCMP 48718**	**UCMP 50552**	**UCMP 50665**	**UCMP 50667**	**UCMP 50670**	**UCMP 50680**	**UCMP 50750**	**UCMP 50909**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Anchitheriinae	Equinae	Anchitheriinae	Equinae	Borophaginae	Equinae	Equinae	Equinae
Tribe	Hipparionini		Hipparionini		Hipparionini	Borophagini	Hipparionini	Hipparionini	Hipparionini
Subtribe						Cynarctina			
Genus	*Hipparion*	*Archaeohippus*	*Scaphohippus*	*Archaeohippus*	*Scaphohippus*	*Tephrocyon*	*Scaphohippus*	*Scaphohippus*	*Scaphohippus*
Species	*tehonensis*		*sumani*	*mourningi*	*sumani*	*rurestris*	*sumani*	*sumani*	*sumani*
Site	Mt. Diablo Country Club 1	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W
Site #	5509	5666	5666	5666	5666	5666	5666	5666	5666
Formation	Green Valley	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente
Region	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Bay Area	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges
Age	Cl3		Ba1		Ba1		Ba1	Ba1	Ba1
Decimal	37.84	34.67	34.67	34.67	34.67	34.67	34.67	34.67	34.67
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML				12.04		20.84	20.34		
2LML	17.82								
3LML		13.36							
2UML			21.72		19.75			20.16	17.52
LTRL									

Repository Specimen #	UCMP 50910	UCMP 50950	UCMP 51000	UCMP 51050	UCMP 51075	UCMP 51080	UCMP 51128	UCMP 51130	UCMP 51170
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Anchitheriinae	Anchitheriinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini				Hipparionini	Hipparionini
Subtribe									
Genus	*Scaphohippus*	*Scaphohippus*	*Scaphohippus*	*Scaphohippus*	*Archaeohippus*	*Archaeohippus*	*Archaeohippus*	*Scaphohippus*	*Scaphohippus*
Species	*sumani*	*sumani*	*sumani*	*sumani*	*mourningi*			*sumani*	*sumani*
Site	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W
Site #	5666	5666	5666	5666	5666	5666	5666	5666	5666
Formation	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente
Region	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges
Age	Ba1	Ba1	Ba1	Ba1				Ba1	Ba1
Decimal	34.67	34.67	34.67	34.67	34.67	34.67	34.67	34.67	34.67
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL	19.29					16.08			
3LPL									
4LPL									
1LML		19.7	19.67	17.47			12.09	23.1	19.04
2LML									
3LML					14.16				
2UML									
LTRL									

Repository Specimen #	**UCMP 51180**	**UCMP 51183**	**UCMP 51230**	**UCMP 51230**	**UCMP 51255**	**UCMP 51300**	**UCMP 51310**	**UCMP 51326**	**UCMP 55002**
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Anchitheriinae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini			Equini
Subtribe									
Genus	*Scaphohippus*	*Scaphohippus*	*Scaphohippus*	*Scaphohippus*	*Scaphohippus*	*Scaphohippus*	*Archaeohippus*	*Archaeohippus*	*Pliohippus*
Species	*sumani*	*sumani*	*sumani*	*sumani*	*sumani*	*sumani*			
Site	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Dry Canyon W	Glory Gorge 1
Site #	5666	5666	5666	5666	5666	5666	5666	5666	5703
Formation	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente	Caliente
Region	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges	Transverse Ranges
Age	Ba1	Ba1	Ba1	Ba1	Ba1	Ba1			Cl2
Decimal	34.67	34.67	34.67	34.67	34.67	34.67	34.67	34.67	34.81
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL		20.54							
3LPL					18.6				
4LPL									
1LML			11.55	21.93			12.04	12.2	
2LML									
3LML									24.58
2UML	19.59					19.22			
LTRL									

Repository Specimen #	UCMP 55095	UCMP 55255	UCMP 56278	UCMP 58222	UCMP 58234	UCMP 58244	UCMP 62771	UCMP 65620	UCMP 67024
Family	Equidae	Equidae	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Borophaginae	Equinae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Hipparionini	Equini	Borophagini	Hipparionini	Hipparionini	Hipparionini	Equini	Hipparionini
Subtribe				Borophagina					
Genus	*Scaphohippus*	*Scaphohippus*	*Pliohippus*	*Epicyon*	*Neohipparion*	*Hipparion*	*Hipparion*	*Pliohippus*	*Hipparion*
Species	*sumani*	*sumani*		*haydeni*	*trampasense*	*tehonense*		*fairbanksi*	
Site	Dry Canyon W	Dry Canyon W	Black Hawk Ranch	Kendall-Mallory 1	Kendall-Mallory 1	Kendall-Mallory 1	Caldecott Tunnel 3	Black Hawk Ranch	Black Hawk Ranch
Site #	5673	5666	3310	6107	6107	6107	6224	3310	3310
Formation	Caliente	Caliente	Green Valley	Contra Costa Group	Contra Costa Group	Contra Costa Group	Orinda	Green Valley	Green Valley
Region	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Transverse Ranges	Transverse Ranges	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area
Age	Ba1	Ba1	Cl3	Cl3	Cl3	Cl3	Cl2	Cl3	Cl3
Decimal	34.75	34.67	37.82	37.82	37.82	37.82	37.83	37.82	37.82
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL						21.6			
3LPL									
4LPL									
1LML	20.39	17.98		34.24					
2LML									
3LML									
2UML			26.77		21.8		20.92	30.53	20.12
LTRL									

Repository Specimen #	UCMP 67959	UCMP 74736	UCMP 74748	UCMP 77031	UCMP 78398	UCMP 78409	UCMP 94816	UCMP 95111	UCMP 95112
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Equinae	Equinae	Equinae
Tribe	Equini	Equini	Equini	Hipparionini	Equini		Hipparionini	Hipparionini	Hipparionini
Subtribe									
Genus	*Pliohippus*	*Acritohippus*	*Acritohippus*	*Hipparion*	*Pliohippus*	*Archaeohippus*	*Hipparion*	*Hipparion*	*Hipparion*
Species		*stylodontus*	*stylodontus*	*tehonense*	*fairbanksi*		*forcei*	*forcei*	*forcei*
Site	Quatal Canyon S 20	Coon Canyon	Coon Canyon	Kendall-Mallory 1	Black Hawk Ranch	Dry Canyon W	Black Hawk Ranch	Black Hawk Ranch	Black Hawk Ranch
Site #	5905	6605	6605	6107	3310	5666	3310	3310	3310
Formation	Caliente	Barstow	Barstow	Contra Costa Group	Green Valley	Caliente	Green Valley	Green Valley	Green Valley
Region	Coast Ranges	Great Basin	Great Basin	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Transverse Ranges	Mojave Desert	Mojave Desert	Bay Area	Bay Area	Transverse Ranges	Bay Area	Bay Area	Bay Area
Age	Cl2			Cl3	Cl3		Cl3	Cl3	Cl3
Decimal	34.82	35.03	35.03	37.82	37.82	34.67	37.82	37.82	37.82
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL	19.62								
4LPL									
1LML			24.5	17.5	23.21	12.95			
2LML									
3LML									
2UML		24.92					20.5	22.85	22.92
LTRL									

Repository Specimen #	UCMP 95113	UCMP 112199	UCMP 112769	UCMP 126141	UCMP 131652	UCMP 131653	UCMP 131661	UCMP 166194	UCMP 166218
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae	Equidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Borophaginae	Equinae
Tribe	Hipparionini	Hipparionini	Hipparionini	Equini	Hipparionini	Hipparionini	Hipparionini	Borophagini	Hipparionini
Subtribe								Cynarctina	
Genus	*Hipparion*	*Neohipparion*	*Hipparion*	*Pliohippus*	*Hipparion*	*Hipparion*	*Hipparion*	*Microtomarctus*	*Merychippus*
Species	*forcei*	*trampasense*	*tehonense*	*fairbanksi*	*forcei*	*forcei*	*forcei*		*californicus*
Site	Black Hawk Ranch	Kendall-Mallory 1	Kendall-Mallory 1	Black Hawk Ranch	Black Hawk Ranch	Black Hawk Ranch	Black Hawk Ranch	Path 15	Path 15
Site #	3310	6107	6107	3310	3310	3310	3310	99563	99563
Formation	Green Valley	Contra Costa Group	Contra Costa Group	Green Valley	Green Valley	Green Valley	Green Valley	Temblor	Temblor
Region	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges
Subregion	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area	Bay Area	San Joaquin Valley	San Joaquin Valley
Age	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3	Cl3	17.3	17.3
Decimal	37.82	37.82	37.82	37.82	37.82	37.82	37.82	36.32	36.32
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL									
4LPL									
1LML								15.3	14.26
2LML									
3LML			21.15						
2UML	20.95	18.6		29.59	21.56	21.53	19.58		
LTRL									

Repository Specimen #	UCMP 166234	UCMP 166250	UCMP 166252	UCMP 166260	UCMP 166271	UCMP 166276	UCMP 166555	UCMP 311296	UCMP 311685
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Anchitheriinae	Equinae	Borophaginae
Tribe	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini	Hipparionini		Hipparionini	Borophagini
Subtribe									Cynarctina
Genus	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Merychippus*	*Desmatippus*	*Scaphohippus*	*Paracynarctus*
Species	*californicus*	*californicus*	*californicus*	*californicus*	*californicus*		*avus*	*sumani*	*kelloggi*
Site	Path 15	Path 15	Path 15	Path 15	Path 15	Path 15	Path 15	Barstow 20	Barstow A-H
Site #	99563	99563	99563	99563	99563	99563	99563	RV6401	RV5201
Formation	Temblor	Temblor	Temblor	Temblor	Temblor	Temblor	Temblor	Barstow	Barstow
Region	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Coast Ranges	Great Basin	Great Basin
Subregion	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	San Joaquin Valley	Mojave Desert	Mojave Desert
Age	17.3	17.3	17.3	17.3	17.3	17.3	17.3	Ba1	Ba2
Decimal	36.32	36.32	36.32	36.32	36.32	36.32	36.32	35.03	35.03
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL		20.32							
3LPL									
4LPL									
1LML				18.09					14.28
2LML									
3LML									
2UML	21.59		17.43		17.83	19.08	19.79	20.79	
LTRL									

Repository Specimen #	UCMP 311732	UCMP 315104	UCMP 315125	UCMP 315197	UCMP 318700	UCMP 320010	UCMP 320013	UCMP 320018	UCMP 320048
Family	Equidae	Equidae	Canidae	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Equinae	Equinae	Borophaginae	Equinae	Borophaginae	Equinae	Equinae	Equinae	Equinae
Tribe	Hipparionini	Equini	Borophagini	Equini	Borophagini	Equini	Equini	Equini	Equini
Subtribe			Cynarctina		Borophagina				
Genus	*Scaphohippus*	*Acritohippus*	*Microtomarctus*	*Pliohippus*	*Borophagus*	*Dinohippus*	*Dinohippus*	*Dinohippus*	*Dinohippus*
Species	*intermontanus*	*stylodontus*	*conferta*	*fairbanksi*	*secundus*	*leidyanus*	*leidyanus*	*leidyanus*	*leidyanus*
Site	Barstow Z			Fish Lake Valley 15	Warren	Warren	Warren	Warren	Warren
Site #	RV5801	RV7212	RV7210	RV7034	RV8102	RV8125	RV6834	RV8107	RV8115
Formation	Barstow	Barstow	Barstow	Esmeralda	Horned Toad	Horned Toad	Horned Toad	Horned Toad	Horned Toad
Region	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin
Subregion	Mojave Desert	Mojave Desert	Mojave Desert	Nevada	Mojave Desert	Mojave Desert	Mojave Desert	Mojave Desert	Mojave Desert
Age	Ba1			Cl2	Hh4	Hh4	Hh4	Hh4	Hh4
Decimal	35.03	35.03	35.03	37.92	35.09	35.09	35.09	35.09	35.09
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL									
3LPL							26.5	28.26	27.8
4LPL									
1LML		16.99	15.36	22.23	27.51	20.61			
2LML									
3LML									
2UML	21.31								
LTRL									

Repository Specimen #	UCMP 320050	UCMP 320053	UCMP 320852	UCMP 320853	UCMP 320854	UCMP 320855	UCMP 320858	UCMP 323375	UCMP (V302~1)
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Equidae	Sciuridae
Subfamily	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	Equinae	
Tribe	Equini	Equini	Hipparionini	Hipparionini	Equini	Hipparionini	Hipparionini	Equini	
Subtribe									
Genus	*Dinohippus*	*Dinohippus*	*Scaphohippus*	*Scaphohippus*	*Acritohippus*	*Scaphohippus*	*Scaphohippus*	*Acritohippus*	
Species	*leidyanus*	*leidyanus*	*intermontanus*	*intermontanus*	*stylodontus*	*intermontanus*	*intermontanus*	*stylodontus*	
Site	Warren	Warren Microsite	Cache Peak		Cache Peak	Cache Peak	Cache Peak	Barstow Z	Kendall-Mallory 1
Site #	RV8110	RV7702	RV8212	RV8215	RV8237	RV8244	RV8228	RV5801	6107
Formation	Horned Toad	Horned Toad	Bopesta	Bopesta	Bopesta	Bopesta	Bopesta	Barstow	Contra Costa Group
Region	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Great Basin	Coast Ranges
Subregion	Mojave Desert	Mojave Desert	Mojave Desert	Mojave Desert	Mojave Desert	Mojave Desert	Mojave Desert	Mojave Desert	Bay Area
Age	Hh4	Hh4	Ba1	Ba1		Ba1	Ba1		Cl3
Decimal	35.09	35.09	35.17	35.17	35.19	35.18	35.18	35.03	37.82
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL			21.74	21.88					
3LPL									
4LPL									
1LML	17.78	21.32					19.27	19.4	
2LML									
3LML									
2UML					20.65	20.65			
LTRL									9.51

Repository Specimen #	UCMP (V302~1)	UO 197	UO 5763	UO 10283	UO 20552	UO 21353	UO 21559	UO 23841	UO 23842
Family	Sciuridae	Equidae	Sciuridae	Equidae	Canidae	Canidae	Canidae	Canidae	Canidae
Subfamily		Equinae	Sciurinae	Equinae	Borophaginae	Borophaginae	Borophaginae	Borophaginae	Borophaginae
Tribe		Equini	Marmotini	Hipparionini	Borophagini	Borophagini	Borophagini	Borophagini	Borophagini
Subtribe					Cynarctina	Borophagina	Cynarctina	Cynarctina	Cynarctina
Genus		*Pliohippus*	*Ammospermophilus*	*Hipparion*	*Tephrocyon*	*Epicyon*	*Paracynarctus*	*Paracynarctus*	*Paracynarctus*
Species		*spectans*	*junturensis*		*rurestris*	*saevus*	*kelloggi*	*kelloggi*	*kelloggi*
Site	Kendall-Mallory 1	John Day Pliocene	Poison Basin	Black Butte	Red Basin	Dalles	Red Basin	Red Basin	Red Basin
Site #	6107		2341	2448			2494		
Formation	Contra Costa Group	Rattlesnake	Juntura	Juntura	Butte Creek	Chenoweth	Butte Creek	Butte Creek	Butte Creek
Region	Coast Ranges	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest
Subregion	Bay Area	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau
Age	Cl3	Hh2	Cl3	Cl3	Ba2	Cl3	Ba2	Ba2	Ba2
Decimal	37.82	44.49	43.76	43.76	43.54	45.55	43.57	43.54	43.54
Source	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement	Measurement
2LPL		26.39							
3LPL									
4LPL									
1LML				22.65	18.64	26.01	17.96	18.36	17.66
2LML									
3LML									
2UML									
LTRL	10.01		7.06						

Repository Specimen #	UO 24191	UO 42501	UO 53807	UO Y-672	UO	UWBM 42690	UWBM 42691	UWBM 42694	UWBM 42695
Family	Canidae	Canidae	Canidae	Equidae	Canidae	Equidae	Equidae	Equidae	Equidae
Subfamily	Borophaginae	Borophaginae	Borophaginae	Equinae	Borophaginae	Equinae	Equinae	Equinae	Equinae
Tribe	Borophagini	Borophagini	Borophagini	Hipparionini	Borophagini	Hipparionini	Hipparionini	Hipparionini	Hipparionini
Subtribe	Cynarctina	Borophagina	Borophagina		Cynarctina				
Genus	*Tephrocyon*	*Epicyon*	*Epicyon*	*Hipparion*	*Tephrocyon*	*Hipparion*	*Hipparion*	*Hipparion*	*Hipparion*
Species	*rurestris*	*saevus*	*haydeni*	*condoni*	*rurestris*				
Site	Red Basin	Black Butte	Black Butte	Ellensburg	Mascall	Zillah	Zillah	Zillah	Zillah
Site #	2495					A9429	A9429	A9429	A9429
Formation	Butte Creek	Juntura	Juntura	Ellensburg	Mascall	Ellensburg	Ellensburg	Ellensburg	Ellensburg
Region	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest
Subregion	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau
Age	Ba2	Cl3	Cl3	Cl3	14.13356239	Cl3	Cl3	Cl3	Cl3
Decimal	43.57	43.76	43.76	46.99	44.51	46.99	46.99	46.99	46.99
Source	Measurement	Measurement	Measurement	Measurement	Downs 1956	Measurement	Measurement	Measurement	Measurement
2LPL						26.74	-	-	-
3LPL						-	-	-	-
4LPL						-	24.47	19.74	21.18
1LML	17.97	29.1	30.77	17.7	20	-	-	-	-
2LML									
3LML						-	-	-	-
2UML						-	-	-	-
LTRL						-	-	-	-

Repository Specimen #	UWBM 42696	UWBM 42697	UWBM 42699	YPM 1128	YPM 11274	YPM 12720
Family	Equidae	Equidae	Equidae	Equidae	Equidae	Canidae
Subfamily	Equinae	Equinae	Equinae	Anchitheriinae	Anchitheriinae	Borophaginae
Tribe	Hipparionini	Hipparionini	Hipparionini			Borophagini
Subtribe						Cynarctina
Genus	*Hipparion*	*Hipparion*	*Hipparion*	*Desmatippus*	*Desmatippus*	*Tephrocyon*
Species				*avus*	*avus*	*rurestris*
Site	Zillah	Zillah	Zillah	Cottonwood Creek	Mascall	Crooked River
Site #	A9429	A9429	A9429			
Formation	Ellensburg	Ellensburg	Ellensburg	Mascall	Mascall	Mascall
Region	Northwest	Northwest	Northwest	Northwest	Northwest	Northwest
Subregion	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau	Columbia Plateau
Age	Cl3	Cl3	Cl3	14.13356239	14.13356239	14.13356239
Decimal	46.99	46.99	46.99	44.50	44.51	44.05
Source	Measurement	Measurement	Measurement	Downs 1956	Downs 1956	Downs 1956
2LPL	-	-	-			
3LPL	-	-	-			
4LPL	-	-	-			
1LML	21.1	23.19	23.58	16.6		21.9
2LML						
3LML	-	-	-			
2UML	-	-	-		17.2	
LTRL	-	-	-			

APPENDIX C

CHAPTER IV RECENT DATA

Repository – Collection in which specimen is located

Specimen # - Identification number of specimen

Taxonomy (Family, Genus, Species) – Specimen taxon

Latitude – Decimal latitude at which specimen was collected

MAT – Mean annual temperature of locality at which specimen was collected

Mass – Mass of specimen (kg for canids and equids, g for sciurids)

Repository	Specimen #	Family	Genus	Species	Latitude	MAT	Mass
MSB	83943	Canidae	*Canis*	*latrans*	29.00	25.30	16.00
MSB	152162	Sciuridae	*Spermophilus*		43.52	5.56	46.40
MSB	152168	Sciuridae	*Spermophilus*		43.52	5.56	121.00
MSB	152289	Sciuridae	*Spermophilus*	*mollis*	43.52	5.56	70.70
MSB	152339	Sciuridae	*Spermophilus*	*mollis*	43.50	5.56	69.60
MSB	152340	Sciuridae	*Spermophilus*	*mollis*	43.50	5.56	63.90
MSB	152352	Sciuridae	*Spermophilus*	*mollis*	43.50	5.56	72.70
MSB	152418	Sciuridae	*Spermophilus*	*mollis*	43.52	5.56	84.30
MSB	152422	Sciuridae	*Spermophilus*	*mollis*	43.52	5.56	78.00
MSB	152424	Sciuridae	*Spermophilus*	*mollis*	43.52	5.56	124.00
MSB	155314	Sciuridae	*Spermophilus*	*columbianus*	44.60	4.44	221.00
MSB	155398	Sciuridae	*Spermophilus*	*beldingi*	41.68	9.61	280.00
MSB	155400	Sciuridae	*Spermophilus*	*lateralis*	41.68	9.61	126.00
MSB	155494	Sciuridae	*Spermophilus*	*beldingi*	41.68	9.61	188.00
MSB	155513	Sciuridae	*Spermophilus*	*lateralis*	44.42	9.94	111.00
MSB	155514	Sciuridae	*Spermophilus*	*lateralis*	44.42	9.94	124.00
MSB	155515	Sciuridae	*Spermophilus*	*lateralis*	44.42	9.94	150.00
MSB	155516	Sciuridae	*Spermophilus*	*lateralis*	44.42	9.94	181.00
MSB	155544	Sciuridae	*Spermophilus*	*beldingi*	44.41	9.94	280.00
MSB	155616	Sciuridae	*Spermophilus*	*columbianus*	45.87	12.00	370.00
MSB	196503	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	540.00
MSB	196504	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	395.00
MSB	196505	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	390.00
MSB	196506	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	330.00
MSB	196507	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	450.00
MSB	196508	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	390.00
MSB	196509	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	350.00
MSB	196510	Sciuridae	*Spermophilus*	*variegatus*	35.51	15.06	358.00
MSB	196511	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	285.00
MSB	196512	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	440.00
MSB	196513	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	358.00
MSB	196514	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	330.00
MSB	196515	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	300.00
MSB	196516	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	345.00
MSB	199681	Sciuridae	*Spermophilus*	*beecheyi*	35.52	15.06	460.00
MSB	199698	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	215.00
MSB	224755	Sciuridae	*Spermophilus*	*beldingi*	42.20	11.83	124.00
MSB	225606	Sciuridae	*Spermophilus*		42.20	11.83	281.00
MSB	227120	Sciuridae	*Spermophilus*	*lateralis*	39.24	7.11	71.00
MSB	227196	Sciuridae	*Spermophilus*	*lateralis*	39.24	7.11	72.00
MSB	227606	Sciuridae	*Spermophilus*	*lateralis*	44.93	8.83	217.00
MSB	227667	Sciuridae	*Spermophilus*	*lateralis*	44.93	7.00	223.00
MSB	230582	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	310.00
MSB	230619	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	385.00
MSB	230644	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	370.00
MSB	230661	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	610.00
MSB	230674	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	345.00
MSB	230680	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	795.00
MSB	230681	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	465.00
MSB	230726	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	220.00
MSB	230735	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	450.00
MSB	230736	Sciuridae	*Spermophilus*	*beecheyi*	35.51	15.06	815.00
MSB	231900	Sciuridae	*Spermophilus*	*parryii*	59.39	5.17	590.00
MSB	232031	Sciuridae	*Spermophilus*	*parryii*	59.40	5.17	595.00
MSB	232032	Sciuridae	*Spermophilus*	*parryii*	59.38	5.17	660.00
MSB	232033	Sciuridae	*Spermophilus*	*parryii*	59.38	5.17	612.00
MSB	232034	Sciuridae	*Spermophilus*	*parryii*	59.39	5.17	556.00

Repository	Specimen #	Family	Genus	Species	Latitude	MAT	Mass
MSB	232052	Sciuridae	*Spermophilus*	*parryii*	59.38	5.17	480.00
MSB	232053	Sciuridae	*Spermophilus*	*parryii*	59.39	5.17	508.00
MSB	232054	Sciuridae	*Spermophilus*	*parryii*	59.38	5.17	432.00
MVZ	191020	Cervidae	*Odocoileus*	*hemionus*	37.90	14.20	18.60
MVZ	191021	Cervidae	*Odocoileus*	*hemionus*	37.90	14.20	40.80
MVZ	201336	Sciuridae	*Spermophilus*	*beecheyi*	37.73	8.50	560.00
MVZ	201337	Sciuridae	*Spermophilus*	*beecheyi*	37.73	8.50	650.00
MVZ	201338	Sciuridae	*Spermophilus*	*beecheyi*	37.73	8.50	562.00
MVZ	201339	Sciuridae	*Spermophilus*	*beecheyi*	37.73	8.50	470.00
MVZ	201340	Sciuridae	*Spermophilus*	*beecheyi*	37.73	8.50	458.00
MVZ	201341	Sciuridae	*Spermophilus*	*beecheyi*	37.73	8.50	614.00
MVZ	201342	Sciuridae	*Spermophilus*	*beecheyi*	37.74	8.50	397.00
MVZ	201343	Sciuridae	*Spermophilus*	*beecheyi*	37.74	8.50	350.00
MVZ	201344	Sciuridae	*Spermophilus*	*beecheyi*	37.75	8.50	579.00
MVZ	201345	Sciuridae	*Spermophilus*	*beecheyi*	37.75	8.50	722.00
MVZ	201346	Sciuridae	*Spermophilus*	*beecheyi*	37.75	8.50	690.00
MVZ	201347	Sciuridae	*Spermophilus*	*beecheyi*	37.75	8.50	728.00
MVZ	201348	Sciuridae	*Spermophilus*	*beecheyi*	37.73	8.50	280.00
MVZ	207146	Sciuridae	*Spermophilus*	*beecheyi*	37.62	17.11	890.00
MVZ	207147	Sciuridae	*Spermophilus*	*beecheyi*	37.62	17.11	942.00
MVZ	207148	Sciuridae	*Spermophilus*	*beecheyi*	37.62	17.11	820.00
MVZ	207149	Sciuridae	*Spermophilus*	*beecheyi*	37.62	17.11	495.00
MVZ	207150	Sciuridae	*Spermophilus*	*beecheyi*	37.62	17.11	872.00
MVZ	207151	Sciuridae	*Spermophilus*	*beecheyi*	37.62	17.11	507.00
MVZ	207152	Sciuridae	*Spermophilus*	*beecheyi*	37.62	17.11	523.00
MVZ	207153	Sciuridae	*Spermophilus*	*beecheyi*	37.62	17.11	600.00
MVZ	207154	Sciuridae	*Spermophilus*	*beecheyi*	37.76	12.56	400.00
MVZ	207156	Sciuridae	*Spermophilus*	*beecheyi*	37.84	8.50	490.00
MVZ	207160	Sciuridae	*Spermophilus*	*beecheyi*	37.73	8.50	291.00
MVZ	207161	Sciuridae	*Spermophilus*	*beecheyi*	37.74	8.50	270.00
MVZ	207162	Sciuridae	*Spermophilus*	*beecheyi*	37.74	8.50	660.00
MVZ	207163	Sciuridae	*Spermophilus*	*beecheyi*	37.74	8.50	840.00
MVZ	207164	Sciuridae	*Spermophilus*	*beecheyi*	37.74	8.50	700.00
MVZ	207165	Sciuridae	*Spermophilus*	*beecheyi*	37.83	8.50	330.00
MVZ	207166	Sciuridae	*Spermophilus*	*beecheyi*	37.75	8.50	665.00
MVZ	207167	Sciuridae	*Spermophilus*	*beecheyi*	37.75	8.50	720.00
MVZ	208499	Sciuridae	*Spermophilus*	*beecheyi*	37.90	8.83	385.00
MVZ	208500	Sciuridae	*Spermophilus*	*beecheyi*	37.95	8.83	256.00
MVZ	216227	Sciuridae	*Spermophilus*	*beecheyi*	37.90	8.83	610.00
MVZ	216228	Sciuridae	*Spermophilus*	*beecheyi*	37.75	8.50	550.00
MVZ	216229	Sciuridae	*Spermophilus*	*beecheyi*	37.80	8.50	700.00
MVZ	216230	Sciuridae	*Spermophilus*	*beecheyi*	37.75	8.50	440.00
MVZ	216231	Sciuridae	*Spermophilus*	*beecheyi*	37.75	8.50	510.00
MVZ	216232	Sciuridae	*Spermophilus*	*beecheyi*	37.90	8.83	215.00
MVZ	216943	Sciuridae	*Spermophilus*	*beecheyi*	36.12	18.28	295.00
MVZ	217733	Sciuridae	*Spermophilus*	*beecheyi*	40.66	9.50	485.00
MVZ	217734	Sciuridae	*Spermophilus*	*beecheyi*	40.66	9.50	519.00
MVZ	217735	Sciuridae	*Spermophilus*	*beecheyi*	40.59	9.50	520.00
MVZ	217736	Sciuridae	*Spermophilus*	*beecheyi*	40.66	9.50	580.00
MVZ	217737	Sciuridae	*Spermophilus*	*beecheyi*	40.66	9.50	450.00
MVZ	217738	Sciuridae	*Spermophilus*	*beecheyi*	40.57	9.50	650.00
MVZ	217739	Sciuridae	*Spermophilus*	*beecheyi*	40.66	9.50	390.00
MVZ	217740	Sciuridae	*Spermophilus*	*beecheyi*	40.66	9.50	420.00
MVZ	217741	Sciuridae	*Spermophilus*	*beecheyi*	40.59	9.50	630.00
MVZ	217983	Sciuridae	*Spermophilus*	*beecheyi*	37.87	14.22	462.00
MVZ	218052	Sciuridae	*Spermophilus*	*beecheyi*	40.34	7.11	640.00
MVZ	218053	Sciuridae	*Spermophilus*	*beecheyi*	40.35	7.11	560.00

Repository	Specimen #	Family	Genus	Species	Latitude	MAT	Mass
MVZ	218054	Sciuridae	*Spermophilus*	*beecheyi*	40.34	7.11	540.00
MVZ	218685	Cervidae	*Odocoileus*	*hemionus*	37.90	14.20	29.50
MVZ	218695	Sciuridae	*Spermophilus*	*beecheyi*	37.40	16.28	641.00
MVZ	218697	Sciuridae	*Spermophilus*	*beecheyi*	37.39	16.28	511.50
MVZ	218698	Sciuridae	*Spermophilus*	*beecheyi*	37.40	16.28	695.00
MVZ	218700	Sciuridae	*Spermophilus*	*beecheyi*	37.40	16.28	715.00
MVZ	218709	Sciuridae	*Spermophilus*	*beecheyi*	37.40	16.28	415.00
MVZ	218715	Sciuridae	*Spermophilus*	*beecheyi*	37.40	16.28	355.30
MVZ	218718	Sciuridae	*Spermophilus*	*beecheyi*	37.41	16.28	344.00
MVZ	219138	Sciuridae	*Spermophilus*	*beecheyi*	40.44	7.11	540.00
MVZ	219139	Sciuridae	*Spermophilus*	*beecheyi*	40.43	7.11	393.00
MVZ	219140	Sciuridae	*Spermophilus*	*beecheyi*	40.43	7.11	493.00
MVZ	219141	Sciuridae	*Spermophilus*	*beecheyi*	40.43	7.11	465.00
MVZ	219214	Sciuridae	*Spermophilus*	*beecheyi*	36.59	15.61	475.00
MVZ	219215	Sciuridae	*Spermophilus*	*beecheyi*	36.80	9.61	450.00
MVZ	219216	Sciuridae	*Spermophilus*	*beecheyi*	36.80	9.61	539.00
MVZ	219217	Sciuridae	*Spermophilus*	*beecheyi*	36.80	9.61	445.00
MVZ	219576	Sciuridae	*Spermophilus*	*beecheyi*	40.39	16.44	600.00
MVZ	219577	Sciuridae	*Spermophilus*	*beecheyi*	40.39	16.44	660.00
MVZ	219659	Sciuridae	*Spermophilus*	*beecheyi*	40.16	17.22	558.00
MVZ	219660	Sciuridae	*Spermophilus*	*beecheyi*	40.16	17.22	485.00
MVZ	219661	Sciuridae	*Spermophilus*	*beecheyi*	40.16	17.22	490.00
MVZ	219662	Sciuridae	*Spermophilus*	*beecheyi*	40.16	17.22	612.00
MVZ	219663	Sciuridae	*Spermophilus*	*beecheyi*	40.16	17.22	521.00
MVZ	220163	Sciuridae	*Spermophilus*	*beecheyi*	40.58	7.11	440.00
MVZ	220336	Sciuridae	*Spermophilus*	*beecheyi*	36.38	13.72	378.00
MVZ	220337	Sciuridae	*Spermophilus*	*beecheyi*	36.38	13.72	547.00
MVZ	220454	Sciuridae	*Spermophilus*	*beecheyi*	40.57	7.11	410.00
MVZ	220495	Sciuridae	*Spermophilus*	*beecheyi*	40.85	9.50	600.00
MVZ	220665	Sciuridae	*Spermophilus*	*beecheyi*	40.45	7.11	470.00
MVZ	220666	Sciuridae	*Spermophilus*	*beecheyi*	40.41	7.11	650.00
MVZ	220667	Sciuridae	*Spermophilus*	*beecheyi*	40.41	7.11	222.70
MVZ	221749	Sciuridae	*Spermophilus*	*beecheyi*	39.25	14.67	485.00
MVZ	221750	Sciuridae	*Spermophilus*	*beecheyi*	39.27	14.67	595.00
MVZ	221751	Sciuridae	*Spermophilus*	*beecheyi*	39.27	14.67	470.00
MVZ	223371	Sciuridae	*Spermophilus*	*beecheyi*	35.67	16.00	358.00
MVZ	223372	Sciuridae	*Spermophilus*	*beecheyi*	35.69	16.00	298.00
MVZ	224844	Sciuridae	*Spermophilus*	*beecheyi*	35.44	16.00	340.00
MVZ	224845	Sciuridae	*Spermophilus*	*beecheyi*	35.44	16.00	302.00
MVZ	224846	Sciuridae	*Spermophilus*	*beecheyi*	36.59	15.61	630.00
MVZ	224847	Sciuridae	*Spermophilus*	*beecheyi*	36.62	15.61	588.00
MVZ	224848	Sciuridae	*Spermophilus*	*beecheyi*	36.79	15.61	400.00
MVZ	224849	Sciuridae	*Spermophilus*	*beecheyi*	36.79	15.61	391.00
MVZ	226261	Sciuridae	*Spermophilus*	*beecheyi*	36.59	15.61	652.00
MVZ	226262	Sciuridae	*Spermophilus*	*beecheyi*	36.59	15.61	492.00
MVZ	226263	Sciuridae	*Spermophilus*	*beecheyi*	37.90	8.83	739.00
MVZ	226264	Sciuridae	*Spermophilus*	*beecheyi*	37.90	8.83	603.00
MVZ	227066	Sciuridae	*Spermophilus*	*beecheyi*	37.90	8.83	588.00
UAM	15991	Cervidae	*Odocoileus*	*hemionus*	57.10	6.60	38.10
UAM	35120	Sciuridae	*Spermophilus*	*saturatus*	47.10	8.39	220.00
UAM	35162	Sciuridae	*Spermophilus*	*parryii*	59.61	5.17	545.00
UAM	35163	Sciuridae	*Spermophilus*	*parryii*	59.61	5.17	535.00
UAM	35164	Sciuridae	*Spermophilus*	*parryii*	59.61	5.17	585.00
UAM	35167	Sciuridae	*Spermophilus*	*parryii*	58.19	-0.80	335.00
UAM	41853	Sciuridae	*Spermophilus*	*beldingi*	45.43	7.94	225.80
UAM	41854	Sciuridae	*Spermophilus*	*beldingi*	45.43	7.94	264.80
UAM	44511	Sciuridae	*Spermophilus*	*beldingi*	45.43	7.94	283.50

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UAM	44512	Sciuridae	*Spermophilus*	*beldingi*	45.43	7.94	248.70
UAM	50371	Sciuridae	*Spermophilus*		45.72	7.94	173.40
UAM	55974	Sciuridae	*Spermophilus*	*parryii*	61.31	-3.06	200.00
UAM	56007	Sciuridae	*Spermophilus*	*parryii*	61.83	-3.06	375.00
UAM	56050	Sciuridae	*Spermophilus*	*parryii*	61.79	-3.06	400.00
UAM	56051	Sciuridae	*Spermophilus*	*parryii*	61.79	-3.06	350.00
UAM	56818	Sciuridae	*Spermophilus*	*parryii*	61.83	-3.06	500.00
UAM	56819	Sciuridae	*Spermophilus*	*parryii*	61.83	-3.06	375.00
UAM	57775	Sciuridae	*Spermophilus*	*parryii*	61.32	-3.06	420.00
UAM	57860	Sciuridae	*Spermophilus*	*parryii*	61.32	-3.06	110.00
UAM	57861	Sciuridae	*Spermophilus*	*parryii*	61.32	-3.06	160.00
UAM	57871	Sciuridae	*Spermophilus*	*parryii*	61.32	-3.06	160.00
UAM	64431	Sciuridae	*Spermophilus*	*parryii*	59.63	5.17	186.00
UAM	64432	Sciuridae	*Spermophilus*	*parryii*	59.63	5.17	238.00
UAM	64572	Sciuridae	*Spermophilus*	*parryii*	59.64	5.17	455.00
UAM	64595	Sciuridae	*Spermophilus*	*parryii*	59.60	5.17	434.00
UAM	100768	Sciuridae	*Spermophilus*	*parryii*	61.16	3.50	444.00
UAM	102369	Sciuridae	*Spermophilus*	*parryii*	61.63	-2.06	660.00
UAM	102417	Sciuridae	*Spermophilus*	*parryii*	60.79	-3.06	455.00
UAM	102418	Sciuridae	*Spermophilus*	*parryii*	60.79	-3.06	580.00
USNM	215841	Sciuridae	*Spermophilus*	*beecheyi*	34.40	16.50	51.80
USNM	215842	Sciuridae	*Spermophilus*	*beecheyi*	34.40	16.50	52.00
USNM	243323	Canidae	*Canis*	*lupus*	56.80	5.89	41.30
USNM	243328	Canidae	*Canis*	*lupus*	56.30	6.61	36.70
USNM	243329	Canidae	*Canis*	*lupus*	56.30	6.61	43.50
USNM	243330	Canidae	*Canis*	*lupus*	56.30	6.61	27.70
USNM	243331	Canidae	*Canis*	*lupus*	56.60	6.61	32.70
USNM	243332	Canidae	*Canis*	*lupus*	56.60	6.61	40.80
USNM	243333	Canidae	*Canis*	*lupus*	56.30	6.61	40.80
USNM	243334	Canidae	*Canis*	*lupus*	55.40	7.33	34.50
USNM	243335	Canidae	*Canis*	*lupus*	55.40	7.33	32.70
USNM	266543	Cervidae	*Odocoileus*	*hemionus*	42.50	8.10	42.00
USNM	275834	Sciuridae	*Spermophilus*	*saturatus*	47.80	8.72	239.70
USNM	275835	Sciuridae	*Spermophilus*	*saturatus*	46.20	11.11	314.00
USNM	275836	Sciuridae	*Spermophilus*	*saturatus*	46.20	11.11	201.00
USNM	484951	Sciuridae	*Spermophilus*	*beecheyi*	38.80	15.56	148.00
USNM	484967	Sciuridae	*Spermophilus*	*elegans*	40.70	8.83	279.70
USNM	484969	Sciuridae	*Spermophilus*	*mollis*	39.20	7.11	135.90
USNM	513838	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	100.00
USNM	513839	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	82.00
USNM	513840	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	97.00
USNM	513841	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	115.00
USNM	513843	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	100.00
USNM	513844	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	178.00
USNM	513846	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	192.00
USNM	513847	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	117.00
USNM	513848	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	147.00
USNM	514041	Sciuridae	*Spermophilus*	*tereticaudus*	29.00	25.30	98.00
USNM	525526	Canidae	*Canis*	*latrans*	26.30	25.30	8.00
USNM	525529	Sciuridae	*Spermophilus*	*tereticaudus*	28.90	25.30	86.00
USNM	528799	Sciuridae	*Spermophilus*	*beecheyi*	32.50	25.30	485.00
USNM	530149	Canidae	*Canis*	*latrans*	28.90	25.30	10.50
USNM	531426	Sciuridae	*Spermophilus*	*atricapillus*	26.40	25.30	350.00
USNM	531427	Sciuridae	*Spermophilus*	*atricapillus*	25.30	25.30	500.00
USNM	531428	Sciuridae	*Spermophilus*	*atricapillus*	25.30	25.30	510.00
USNM	565927	Sciuridae	*Spermophilus*	*brunneus*	44.10	11.06	194.00
UWBM	12561	Canidae	*Canis*	*latrans*	47.60	10.28	7.27

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UWBM	32821	Canidae	*Canis*	*latrans*	48.10	10.61	8.30
UWBM	33347	Canidae	*Canis*	*latrans*	47.80	11.33	14.40
UWBM	35534	Canidae	*Canis*	*latrans*	48.30	10.50	11.82
UWBM	38272	Canidae	*Canis*	*latrans*	47.60	11.61	7.30
UWBM	38273	Canidae	*Canis*	*latrans*	47.60	11.61	11.90
UWBM	38275	Canidae	*Canis*	*latrans*	47.70	11.33	12.20
UWBM	38276	Canidae	*Canis*	*latrans*	47.50	10.28	8.45
UWBM	38277	Canidae	*Canis*	*latrans*	47.70	11.33	9.95
UWBM	38278	Canidae	*Canis*	*latrans*	47.70	11.33	11.50
UWBM	38279	Canidae	*Canis*	*latrans*	47.50	10.28	9.65
UWBM	38280	Canidae	*Canis*	*latrans*	47.50	10.28	9.45
UWBM	38281	Canidae	*Canis*	*latrans*	47.50	10.28	9.20
UWBM	38282	Canidae	*Canis*	*latrans*	47.70	11.33	10.40
UWBM	38283	Canidae	*Canis*	*latrans*	47.50	10.28	11.15
UWBM	38284	Canidae	*Canis*	*latrans*	47.50	10.28	10.35
UWBM	38285	Canidae	*Canis*	*latrans*	47.50	10.28	12.15
UWBM	38287	Canidae	*Canis*	*latrans*	47.70	11.33	11.14
UWBM	38292	Canidae	*Canis*	*latrans*	47.50	10.28	11.85
UWBM	38294	Canidae	*Canis*	*latrans*	47.80	11.33	9.80
UWBM	38295	Canidae	*Canis*	*latrans*	47.70	11.33	11.60
UWBM	38296	Canidae	*Canis*	*latrans*	47.70	11.33	7.75
UWBM	38297	Canidae	*Canis*	*latrans*	47.50	10.28	9.10
UWBM	38298	Canidae	*Canis*	*latrans*	46.90	9.78	15.90
UWBM	38299	Canidae	*Canis*	*latrans*	47.80	11.30	11.20
UWBM	38300	Canidae	*Canis*	*latrans*	47.50	10.28	5.00
UWBM	38303	Canidae	*Canis*	*latrans*	46.90	9.78	9.40
UWBM	38304	Canidae	*Canis*	*latrans*	47.70	11.33	13.60
UWBM	38305	Canidae	*Canis*	*latrans*	47.70	10.28	12.10
UWBM	38306	Canidae	*Canis*	*latrans*	47.70	11.33	12.40
UWBM	38307	Canidae	*Canis*	*latrans*	47.70	11.33	15.10
UWBM	38308	Canidae	*Canis*	*latrans*	46.90	9.78	10.10
UWBM	38309	Canidae	*Canis*	*latrans*	47.50	10.28	9.25
UWBM	38310	Canidae	*Canis*	*latrans*	47.50	10.28	12.80
UWBM	38311	Canidae	*Canis*	*latrans*	47.70	11.33	13.35
UWBM	38312	Canidae	*Canis*	*latrans*	47.50	10.28	10.65
UWBM	38313	Canidae	*Canis*	*latrans*	47.50	10.28	9.85
UWBM	38314	Canidae	*Canis*	*latrans*	47.50	10.28	10.05
UWBM	38315	Canidae	*Canis*	*latrans*	47.70	11.33	13.40
UWBM	38316	Canidae	*Canis*	*latrans*	47.50	10.28	11.85
UWBM	38317	Canidae	*Canis*	*latrans*	47.50	10.28	9.80
UWBM	38318	Canidae	*Canis*	*latrans*	47.50	10.28	10.80
UWBM	38319	Canidae	*Canis*	*latrans*	47.50	10.28	12.15
UWBM	38320	Canidae	*Canis*	*latrans*	47.50	10.28	8.90
UWBM	38321	Canidae	*Canis*	*latrans*	47.70	11.33	9.40
UWBM	38322	Canidae	*Canis*	*latrans*	47.50	10.28	5.80
UWBM	38323	Canidae	*Canis*	*latrans*	47.50	10.28	13.15
UWBM	38324	Canidae	*Canis*	*latrans*	47.70	11.33	10.10
UWBM	38325	Canidae	*Canis*	*latrans*	47.50	10.28	11.80
UWBM	38326	Canidae	*Canis*	*latrans*	47.60	11.30	4.70
UWBM	38626	Canidae	*Canis*	*latrans*	42.90	6.78	11.25
UWBM	38627	Canidae	*Canis*	*latrans*	42.90	6.78	10.34
UWBM	39393	Canidae	*Canis*	*latrans*	47.60	8.00	10.90
UWBM	39394	Canidae	*Canis*	*latrans*	47.70	11.33	8.90
UWBM	39395	Canidae	*Canis*	*latrans*	48.30	10.50	9.77
UWBM	60984	Canidae	*Canis*	*latrans*	47.20	10.94	7.70
UWBM	60985	Canidae	*Canis*	*latrans*	47.20	10.94	9.50
UWBM	60986	Canidae	*Canis*	*latrans*	47.20	10.94	6.80

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UWBM	79559	Canidae	*Canis*	*latrans*	47.50	10.94	3.21
UWBM	81147	Canidae	*Canis*	*latrans*	48.50	8.30	5.80
UWBM	81148	Canidae	*Canis*	*latrans*	48.50	8.30	5.20
UWBM	81149	Canidae	*Canis*	*latrans*	47.10	9.89	2.60
UWBM	81785	Canidae	*Canis*	*latrans*	47.40	11.28	5.58
UWBM	81801	Canidae	*Canis*	*latrans*	47.80	11.61	9.53
UWBM	81805	Canidae	*Canis*	*latrans*	47.40	11.28	11.24

REFERENCES CITED

Alroy, J. 1998. Cope's rule and the dynamics of body mass evolution in North American fossil mammals. Science 280:731-734.

Alroy, J. 2003. Taxonomic inflation and body mass distributions in North American fossil mammals. Journal of Mammalogy 84:431-443.

Alroy, J., P.L. Koch, and J.C. Zachos. 2000. Global climate change and North American mammal evolution. Paleobiology 26:259-288.

Ashton, K.G., M.C. Tracy, and A. de Quiroz. 2000. Is Bergmann's Rule valid for mammals? American Naturalist 156:390-415.

Ashton, K.G. 2002a. Do amphibians follow Bergmann's Rule? Canadian Journal of Zoology 80:708-716.

Ashton, K.G. 2002b. Patterns of within-species body size variation of birds: strong evidence for Bergmann's Rule. Global Ecology and Biogeography 11:505-523.

Ashton, K.G., and C.R. Feldman. 2003. Bergmann's Rule in nonavian reptiles: turtles follow it, lizards and snakes reverse it. Evolution 57:1151-1163.

Barnosky, A.D. 2001. Distinguishing the effects of the Red Queen and the Court Jester on Miocene mammal evolution in the northern Rocky Mountains. Journal of Vertebrate Paleontology 21:172-185.

Barnosky, A.D., E.A. Hadly, and C.J. Bell. 2003. Mammalian response to global warming on varied temporal scales. Journal of Mammalogy 84:354-368.

Behrensmeyer, A.K., S.M. Kidwell, and R.A. Gastaldo. 2000. Taphonomy and paleobiology. Paleobiolgy 26:103-147.

Bergmann, C. 1847. Ueber die Verhältnisse der Wärmeökonomie der Thiere zu ihrer Grösse. Gottinger Studien 3:595-708.

Berteaux, D., M.M. Humphries, C.J. Krebs, M. Lima, A.G. McAdam, N. Pettorelli, D. Réale, T. Saitoh, E. Tkadlec, R.B. Weladji, and N.C. Stenseth. 2006. Constraints to projecting the effects of climate change on mammals. Climate Research 32:151-158.

Black, C.G. 1963. A review of North American Tertiary Sciuridae. Bulletin of the Museum of Comparative Zoology 130:1-248.

Blackburn, T.M., and K.J. Gaston. 1996. Spatial patterns in the body sizes of bird species in the New World. Oikos 77:436-446.

Blackburn, T.M., and B.A. Hawkins. 2004. Bergmann's Rule and the mammal fauna of northern North America. Ecography 27:715-724.

Bowen, R.G., W.L. Gray, and D.C. Gregory. 1963. General geology of the northern Juntura Basin. Transactions of the American Philosophical Society 53:22-34.

Bradshaw, W.E., and C.M. Holzapfel. 2010. Light, time, and the physiology of biotic response to rapid climate change in animals. Annual Review of Physiology 72:147-166.

Bravo-Cuevas, V.M., and I. Ferrusquía-Villafranca. 2006. *Merychippus* (Mammalia, Perissodactyla, Equidae) from the Middle Miocene of state of Oaxaca, southeastern Mexico. Geobios 39:771-784.

Calede, J.J.M., S.S.B. Hopkins, and E.B. Davis. 2011. Turnover in burrowing rodents: the roles of competition and habitat change. Palaeogeography, Palaeoclimatology, Palaeoecology 311:242-255.

Camp, V.E., M.E. Ross, and W.E. Hanson. 2003. Genesis of flood basalts and Basin and Range volcanic rocks from Steens Mountain to the Malheur River Gorge, Oregon. Geological Society of America Bulletin 115:105-128.

Carrasco, M.A., B.P. Kraatz, E.B. Davis, and A.D. Barnosky. 2005. Miocene Mammal Mapping Project (MIOMAP). http://www.ucmp.berkeley.edu/miomap/

Creighton, G.K. 1980. Static allometry of mammalian teeth and the correlation of tooth size and body size in contemporary mammals. Journal of the Zoological Society of London 191:435-443.

Damuth, J. 1993. Cope's rule, the island rule and the scaling of mammalian population density. Nature 365:748-750.

Darwin, C.R. 1859. On the Origin of Species by Means of Natural Selection. John Murray, London, 502 pp.

Davis, E.B., and N.D. Pyenson. 2007. Diversity biases in terrestrial mammalian assemblages and quantifying the differences between museum collections and published accounts: a case study from the Miocene of Nevada. Palaeogeography, Palaeoclimatology, Palaeoecology 250:139-149.

Downing, K.F. 1992. Biostratigraphy, Taphonomy, and Paleoecology of Vertebrates from the Sucker Creek Formation (Miocene) of Southeastern Oregon. PhD Dissertation, University of Arizona, Tucson, 485 pp.

Downs, T. 1956. The Mascall fauna from the Miocene of Oregon. University of California Publications in Geological Sciences 31:199-354.

Erlinge, S. 1987. Why do European stoats *Mustela erminea* not follow Bergmann's Rule? Holarctic Ecology 10:33-39.

Gingerich, P.D. 2003. Mammalian responses to climate change at the Paleocene-Eocene boundary: Polecat Bench record in the northern Bighorn Basin, Wyoming. Geological Society of America Special Paper 369:463-478.

Goodwin, H.T. 2008. Sciuridae; pp. 355-376 in C.M. Janis, G.F. Gunnell, and M.D. Uhen (ed.), Evolution of Tertiary Mammals of North America Vol. 2: Small Mammals, Xenarthrans, and Marine Mammals. Cambridge University Press, Cambridge.

Gotelli, N.J., and A.M. Ellison. 2004. A Primer of Ecological Statistics. Sinauer, Sunderland, 510 pp.

Gould, G.C., and B.J. MacFadden. 2004. Gigantism, dwarfism, and Cope's rule: "nothing in evolution makes sense without a phylogeny." Bulletin of the American Museum of Natural History 285:219-237.

Henshaw, P.C. 1942. A Tertiary mammalian fauna from the San Antonio Mountains near Tonopah, Nevada. Carnegie Institute of Washington Contributions to Paleontology 530:77-168.

Hollister, E.B., A.S. Englewood, A.J.M. Hammett, T.L. Provin, H.H. Wilkinson, and T.J. Gentry. 2010. Shifts in microbial community structure along an ecological gradient of hypersaline soils and sediments. The ISME Journal 4:829-838.

Hooper, P.R., G.B. Binger, and K.R. Lees. 2002. Ages of the Steens and Columbia River flood basalts and their relationship to extension-related calc-alkalic volcanism in eastern Oregon. Geological Society of America Bulletin 114:43-50.

Hopkins, S.S.B. 2007. Causes of lineage decline in the Aplodontidae: testing for the influence of physical and biological change. Palaeogeography, Palaeoclimatology, Palaeoecology 246:331-353.

Hopkins, S.S.B. 2008. Reassessing the mass of exceptionally large rodents using toothrow length and area as proxies for body mass. Journal of Mammalogy 89:232-243.

Humboldt, A., and A. Bonpland. 1807. *Essay on the Geography of Plants.* Schoell, Paris, 296 pp.

James, F.C. 1970. Geographic size variation in birds and its relationship to climate. Ecology 51:365-390.

Hunt, R. M. 1998. Amphicyonidae; pp. 196-221 in C. M. Janis, K. M. Scott, and L. L. Jacobs (ed.), Evolution of Tertiary Mammals of North America. Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: Synthesis Report. IPCC, Geneva, 104 pp.

Janis, C.M. 1990. Correlation of cranial and dental variables with body size in ungulates and macropodoids; pp. 255-299 in J. Damuth, and B.J. MacFadden (ed.), Body Size in Mammalian Paleobiology. Cambridge University Press, Cambdridge.

Janis, C.M., J. Damuth, and J.M. Theodor. 2000. Miocene ungulates and terrestrial primary productivity: where have all the browsers gone? Proceedings of the National Academy of Sciences 97:7899-7904.

Kellogg, L. 1910. Rodent fauna of the Late Tertiary beds of Virgin Valley and Thousand Creek, Nevada. University of California Publications in Geological Sciences 5:421-437.

Koch, P.L. 1986. Clinal geographic variation in mammals: implications for the study of chronoclines. Paleobiology 12:269-281.

Korpimäki, E., and K. Norrdahl. 1989. Avian predation on mustelids in Europe 1: occurrence and effects on body size variation and life traits. Oikos 55:205-215.

Lillegraven, J.A. 1972. Ordinal and familial diversity of Cenozoic mammals. Taxon 21:261-274.

Lindsey, C.C. 1966. Body sizes of poikilotherm vertebrates at different latitudes. Evolution 20:456-465.

MacFadden, B.J. 1986. Fossil horses from "Eohippus" (*Hyracotherium*) to *Equus*: scaling, Cope's Law, and the evolution of body size. Paleobiology 12:355-369.

MacFadden, B.J. 1992. Fossil Horses: Systematics, Paleobiology, and Evolution of the Family Equidae. Cambridge University Press, Cambridge, 369 pp.

MacFadden, B.J., N. Solounias, and T.E. Cerling. 1999. Ancient diets, ecology, and extinction of 5-million-year-old horses from Florida. Science 283:824-827.

Martin, J. E. 1997. Progression of borophagines (Carnivora: Canidae) in the Pacific Northwest. Journal of Vertebrate Paleontology 17:62A.

Martin, J.E., and D.C. Pagnac. 2009. A vertebrate assemblage from the Miocene Rattlesnake Ridge Member of the Ellensburg Formation, central Washington. Museum of Northern Arizona Bulletin 65:197-216.

Martin, L. D. 1998. Felidae; pp. 236–242 in C. M. Janis, K. M. Scott, and L. L. Jacobs (ed.), Evolution of Tertiary Mammals of North America. Cambridge University Press, Cambridge.

Meiri, S., and T. Dayan. 2003. On the validity of Bergmann's Rule. Journal of Biogeography 30:331-351.

Millar, J.S., and G.J. Hickling. 1990. Fasting endurance and the evolution of mammalian body size. Functional Ecology 4:5-12.

Morea, M.F. 1981. The Massacre Lake Local Fauna (Mammalia, Hemingfordian) from Northwestern Washoe County, Nevada. PhD Dissertation, University of California, Riverside, 262 pp.

Munthe, K. 1989. The skeleton of the Borophaginae (Carnivora: Canidae). University of California Publications in Geological Sciences 133:1-115.

Prothero, D.R. 2004. Did impacts, volcanic eruptions, or climate change affect mammalian evolution? Palaeogeography, Palaeoclimatology, Palaeoecology 214:283-294.

Ray, C. 1960. The application of Bergmann's and Allen's rules to the poikilotherms. Journal of Morphology 106:85-108.

Retallack, G.J. 2004a. Late Oligocene bunch grassland and early Miocene sod grassland paleosols from central Oregon, USA. Palaeogeography, Palaeoclimatology, Palaeoecology 207:203-237.

Retallack, G.J. 2004b. Ecological polarities of mid-Cenozoic fossil plants and animals from central Oregon. Paleobiology 30:561-588.

Retallack, G.J. 2005. Pedogenic carbonate proxies for amount and seasonality of precipitation in paleosols. Geology 33:333-336.

Retallack, G.J. 2007. Cenozoic paleoclimate on land in North America. Journal of Geology 115:271-294.

Riedman, M. 1990. The Pinnipeds: Seals, Sea Lions, and Walruses. University of California Press, Berkeley, 439 pp.

Rodríguez, M.Á., M.Á. Olalla-Tárraga, and B.A. Hawkins. 2008. Bergmann's Rule and the geography mammal body size in the Western Hemisphere. Global Ecology and Biogeography 17:274-283.

Rose, P.J., D.L. Fox, J. Marcot, and C. Badgley. 2011. Flat latitudinal gradient in Paleocene mammal richness suggests decoupling of climate and biodiversity. Geology 39:163-166.

Rosenzweig, M.L. 1968. The strategy of body size in mammalian carnivores. American Midland Naturalist 80:299-315.

Royer, D.L. 1999. Depth to pedogenic carbonate horizon as a paleoprecipitation indicator? Geology 27:1123-1126.

Russell, D. E. 1956. Clarendonian Fauna of Juntura, Oregon. M.A. thesis, University of California, Berkeley, 95 pp.

Schad, W. 1977. Man and Mammals: Toward a Biology of Form. Waldorf, New York, 302 pp.

Sheldon, N.D., G.J. Retallack, and S. Tanaka. 2002. Geochemical climofunctions from North American soils and application to paleosols across the Eocene-Oligocene boundary in Oregon. Journal of Geology 110:687-696.

Shotwell, J.A. 1961. Late Tertiary biogeography of horses in the Northern Great Basin. Journal of Paleontology 35:203-217.

Shotwell, J. A. 1963. Pliocene mammalian communities of the Juntura Basin. Transactions of the American Philosophical Society 53:7-21.

Shotwell, J.A. 1968. Miocene mammals of southeast Oregon. Bulletin of the University of Oregon Museum of Natural History 14:1-67.

Shotwell, J.A. 1970. Pliocene mammals of southeast Oregon and adjacent Idaho. Bulletin of the University of Oregon Museum of Natural History 17:1-103.

Shotwell, J. A., and D. E. Russell. 1963. Mammalian fauna of the upper Juntura Formation, the Black Butte local fauna. Transactions of the American Philosophical Society 53:42-69.

Simpson, G.G. 1964. Species density of North American recent mammals. Systematic Biology 13:57-73.

Smith, F.A., A.G. Boyer, J.H. Brown, D.P. Costa, T. Dayan, S.K.M. Ernest, A.R. Evans, M. Fortelius, J.L. Gittleman, M.J. Hamilton, L.E. Harding, K. Lintulaakso, S.K. Lyons, C. McCain, J.G. Okie, J.J. Saarinen, R.M. Sibly, P.R. Stephens, J. Theodor, and M.D. Uhen. 2010. The evolution of maximum body size of terrestrial mammals. Science 330:1216-1219.

Smith, K.F., and J.H. Brown. 2002. Patterns of diversity, depth range and body size among pelagic fishes along a gradient of depth. Global Ecology and Biogeography 11:313-322.

Tedford, R.H., L.B. Albright III, A.D. Barnosky, I. Ferrusquia-Villafranca, R.M. Hunt, Jr., J.E. Storer, C.C. Swisher III, M.R. Voorhies, S.D. Webb, and D.P. Whistler. 2004. Mammalian biochronology of the Arikareean through Hemphillian interval (late Oligocene through early Pliocene Epochs); pp. 169-231 in M.O. Woodburne (ed.), Late Cretaceous and Cenozoic Mammals of North America. Columbia University Press, New York.

Tedford, R.H., X. Wang, and B.E. Taylor. 2009. Phylogenetic systematics of the North American fossil Caninae (Carnivora: Canidae). Bulletin of the American Museum of Natural History 325:1-218.

Trites, A.W., and D. Pauly. 1998. Estimating mean body masses of marine mammals from maximum body lengths. Canadian Journal of Zoology 76:886-896.

Turner, A., and M. Antón. 1997. The Big Cats and Their Fossil Relatives. Columbia University Press, New York, 234 pp.

Van Valkenburgh, B. 1990. Skeletal and dental predictors of body mass in carnivores; pp. 181-206 in J. Damuth, and B.J. MacFadden (ed.), Body Size in Mammalian Paleobiology. Cambridge University Press, Cambridge.

Van Valkenburgh, B., X. Wang, and J. Damuth. 2004. Cope's rule, hypercarnivory, and extinction in North American canids. Science 306:101-104.

Wallace, R.E. 1946. A Miocene mammalian fauna from Beatty Buttes, Oregon. Carnegie Institution Contributions to Paleontology 551:113-134.

Wang, X. 1994. Phylogenetic systematics of the Hesperocyoninae (Carnivora: Canidae). Bulletin of the American Museum of Natural History 221:1-207.

Wang, X., and R.H. Tedford. 2008. Dogs: Their Fossil Relatives and Evolutionary History. Columbia University Press, New York, 219 pp.

Wang, X., R.H. Tedford, and B. E. Taylor. 1999. Phylogenetic systematics of the Borophaginae (Carnivora: Canidae). Bulletin of the American Museum of Natural History 243:1-391.

Yang, J., R.A. Spicer, T.E.V. Spicer, and C. Li. 2011. 'CLAMP Online': a new web-based tool and its application to the terrestrial Paleocene and Neogene of North America. Paleobiology and Paleoenvironment 91:163-183.

Zachos, J., M. Pagani, L. Sloan, E. Thomas, and K. Billups. 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. Science 292:686-693.