Chapter 11

New Late Uintan to Early Hemingfordian Land Mammal Assemblages from the Undifferentiated Sespe and Vaqueros Formations, Orange County, and from the Sespe and Equivalent Marine Formations in Los Angeles, Santa Barbara, and Ventura Counties, Southern California

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ABSTRACT

Studies of fossil remains of age-diagnostic land mammals have allowed recognition of assemblages of late Uintan, early and late Arikareean, and early Hemingfordian (late middle Eocene, early Oligocene to early Miocene) age in the Sespe Formation and equivalent marine formations of the northern Peninsular Ranges Provinces and western Transverse Ranges in Los Angeles, Orange, Santa Barbara, and Ventura counties, southern California. Recent fossil recovery efforts have resulted in the recognition of new land mammal assemblages in the Santa Ana Mountains and San Joaquin Hills of Orange County, the Santa Monica Mountains of Los Angeles County, and Simi Valley, Ventura County. The late Arikareean fauna appears to represent a new assemblage that has not been recognized previously in the fossil land mammal record of southern California. The presence of a late Uintan assemblage near the base of the undifferentiated Sespe and Vaqueros formations (S/V) in the northern Santa Ana Mountains of Orange County suggests that the base of the unit is similar in age to the base of the Sespe Formation in the Simi Valley area. The top of the S/V in the northern Santa Ana Mountains and San Joaquin Hills of Orange County and in the Santa Monica Mountains of Los Angeles County is approximately 10.4 million years younger than the top the Sespe Formation in the Simi Valley area, at South Mountain, and along Oak Ridge in Ventura County. In the northern Santa Ana Mountains and the Santa Monica Mountains, early Hemingfordian land mammal assemblages occur stratigraphically below late Hemingfordian land mammal assemblages in the overlying marine and continental Topanga Formation.

INTRODUCTION

Fossil recovery efforts conducted over the past 20 years in strata exposed during major earth-moving projects have yielded over 4,000 fossil vertebrate specimens from more than 100 fossil localities in exposures of the continental Sespe Formation and the undifferentiated Sespe and marine Vaqueros formations in the Santa Ana Mountains and San Joaquin Hills of the northern Peninsular Ranges Province in Orange County, southern California (fig. 11.1). Most of these specimens are isolated rodent teeth recovered from both continental and marine strata using a combination of underwater sieving and heavy-liquid separation techniques.

The Sespe Formation in the western Transverse Ranges Province of southern California

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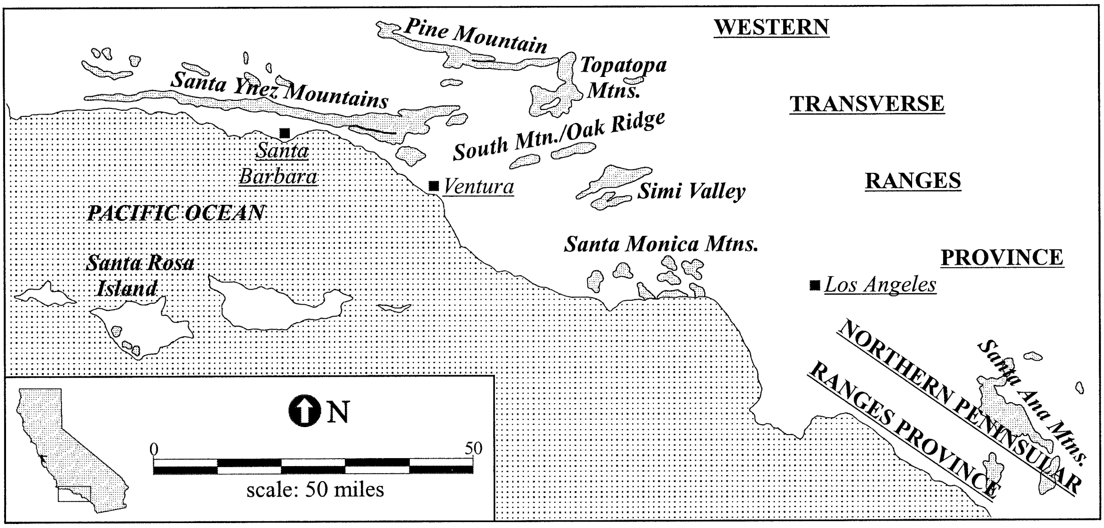


Fig. 11.1. Generalized map of southern California showing exposures (stippled pattern) of Sespe Formation and undifferentiated Sespe/Vaqueros formations (after Howard, 1989).

is known for its late middle Eocene to late Oligocene (late Uintan, Duchesnean, Orellan or Whitneyan, early Arikareean) fossil land mammal assemblages (fig. 11.1; Golz and Lillegraven, 1977; Lander, 1983, 1997; Prothero et al., 1996; Lander et al., 2001). Typical exposures of the Sespe Formation in the western Transverse Ranges are composed of massive red, tan, and light gray to white sandstone and conglomerate layers that are interbedded with variegated or darker reddish-brown mudstone and claystone layers (redbeds) up to several meters thick. The mudstone and claystone layers probably represent paleosols (fossil soil horizons; Lander, 1997). Often, the formation has a characteristic red color that contrasts with the underlying and overlying, lighter-colored, dominantly marine formations of the southern California continental margin.

Variegated or redbed sequences, often interbedded with greenish-gray marine sandstone sequences, are common in the foothills of the Santa Ana Mountains and in the San Joaquin Hills of Orange County (fig. 11.2). In the northern Santa Ana Mountains and in the San Joaquin Hills, the strata constituting these sequences are referred to as the undifferentiated Sespe and Vaqueros formations (S/V) because of the difficulty in distinguishing between the typically continental Sespe Formation and the typically marine Vaqueros Formation (Schoellhamer et al., 1981). However, in the southern Santa Ana Mountains and western Transverse Ranges Province, the Vaqueros Formation clearly overlies the Sespe Formation (Jennings, 1959; Jennings and Strand, 1969; Morton and Miller, 1981), although the formations still exhibit some interdigitation at their contact (Lander, 1983, 1994a, 1997; Lander et al., 2001).

In addition to the vertebrate faunas of late Uintan (first local record), Arikareean, and early Hemingfordian age reported below, the S/V has yielded early? Oligocene to early Miocene marine vertebrate and invertebrate assemblages (see below). The underlying Santiago Formation has yielded middle Eocene marine invertebrates, and the overlying Topanga Formation has yielded abundant early to middle Miocene marine invertebrates and a few land mammals that are as old as early late Hemingfordian in age (see below). These assemblages constitute a composite biostratigraphic framework that constrains the ages of the fossil-bearing strata in the S/V.

The purposes of this study are to document the new vertebrate fossil assemblages in the S/V, particularly those in Orange County, and to construct a revised biostratigraphic framework for vertebrate fossil assemblages found in the Sespe Formation and

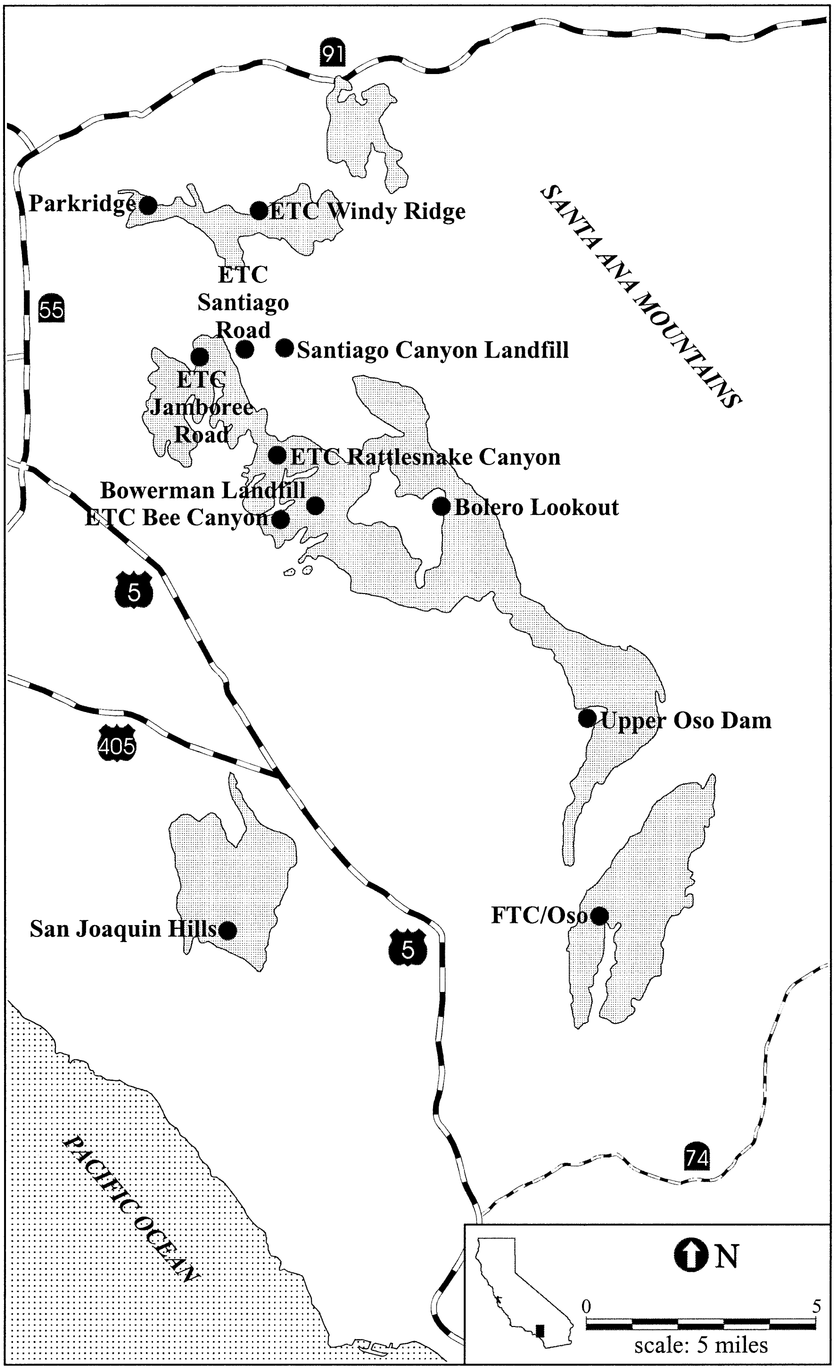


Fig. 11.2. Generalized map of Santa Ana Mountains and San Joaquin Hills, southern Orange County, California, showing exposures (stippled pattern) of Sespe Formation and undifferentiated Sespe/Vaqueros formations and locations of study areas discussed in the text (after Davis, 1978).

equivalent marine formations of southern California.

METHODS

Except for the Bolero Lookout assemblage from LACM (CIT) 449 (Schoellhamer et al., 1981; Belyea and Minch, 1989; Lucas et al., 1997), all of the fossil land mammal assemblages from Orange County referred to in this study were recovered during the past 20 years from strata exposed by grading for major construction projects. The recovery of these specimens resulted from Orange County and local authorizing agency environmental guidelines that require paleontologic monitoring of grading and the recovery, treatment, and permanent storage of uncovered fossils. Projects have ranged in size from a few tens of acres for small housing developments to a 22-mile-long, eight-lane toll road for which 70 million cubic yards of rock were excavated. Similar policies in Ventura County also have resulted in the recovery of numerous fossil remains from the Sespe Formation. Paleontologic monitoring and fossil recovery are conducted by environmental consulting firms under resource impact mitigation programs.

The firms responsible for recovering most of the fossil specimens representing the assemblages discussed below are LSA Associates, Inc. (LSA), Paleo Environmental Associates, Inc. (PEAI), and RMW Paleo Associates, Incorporated (RMW). Some early recovery efforts also were conducted by the Vertebrate Paleontology Department of the Natural History Museum of Los Angeles County. Most of the consulting firms follow Society of Vertebrate Paleontology (SVP) standard guidelines (SVP, 1991, 1995, 1996). Although stratigraphic sections were measured for most of the fossil-producing sequences discussed below, a stratigraphic framework is lacking for some because of the limited areal extent of the fossil-bearing strata or the presence of faulting or slumping, which preclude the measuring of stratigraphic sections, or the failure of some consulting firms to measure sections.

The results of the mitigation work referred to above are recorded in unpublished mitigation program reports filed with the appropriate authorizing agencies. Because most of these reports are not readily available to the scientific community, their results are summarized here. A listing of the reports is provided in the appendix, and copies of most are on file at the Vertebrate Paleontology Department of the Natural History Museum of Los Angeles County.

A major emphasis of some of the mitigation programs involved underwater sieving of large volumes of fossil-bearing rock to recover microvertebrate specimens. Most Tertiary rocks of southern California are sufficiently indurated to require presoaking in dilimonene or another similar dispersant to accelerate the disaggregation of the rock in water. Much of the underwater sieving was conducted under the supervision of M. A. Roeder (PEAI) in automated machines. Sieving was carried out in screens with a minimum sieve size of 0.5 mm (30 mesh). More than 70 tons of sedimentary rock were processed to recover the thousands of microvertebrate specimens that are the focus of this study. Heavy-liquid separation techniques using sodium polytungstate and/or tetrabromoethane were used by one of the authors (D.P.W.) to further concentrate the fossils in the sand concentrates derived from underwater sieving. Isolated micro-mammal teeth are the taxonomically diagnostic elements most commonly recovered by this combination of techniques. If skulls or jaws are present in a matrix sample, they usually are fractured sufficiently that they break up during the sieving process. Larger vertebrate fossil specimens were recovered using standard field jacketing techniques.

D.P.W. identified the continental microvertebrates recovered from the Sespe and Topanga formations and the S/V, and the larger vertebrates recovered from Parkridge parcel. E.B.L. identified most of the larger land mammals recovered from the various collecting areas along the Eastern Transportation Corridor, the Foothill Transportation Corridor Oso Segment, the Santiago Canyon Landfill in Orange County, and the Blakeley Western parcel in Ventura County. H. W. Wagner (SDNHM), G. E. Lewis (USGS), S. G. Lucas, and D.P.W. identified the land mammals from Bolero Lookout in Orange County. Wagner, R.H. Tedford, and X. Wang also identified the carnivores from the ETC, the FTC Oso Segment, and the Santiago Canyon Landfill. S. W. Conkling (LSA) identified the larger land mammals from the San Joaquin Hills Transportation Corridor. R. E. Raschke (RMW) and D.P.W. identified the larger land mammal remains from the Frank R. Bowerman Landfill. S/V fossil collections from Orange County are stored in three repositories, LACM, LC, and OCPC, which is currently under the supervision of California State University, Fullerton.

ABBREVIATIONS

Institutions and Consulting Firms

AMNH	American Museum of Natural History
CMNH	Carnegie Museum of Natural History
ETC	Eastern Transportation Corridor
FTC	Foothill Transportation Corridor
LACM	Vertebrate Paleontology Department, Natural History Museum of Los Angeles County
LACM (CIT)	California Institute of Technology (now at LACM)
LC	Ralph B. Clark Interpretive Center, Los Coyotes Regional Park, Buena Park
LSA	LSA Associates, Inc.
OCPC	Orange County Paleontological Collection
PEAI	Paleo Environmental Associates, Inc.
RMW	RMW Paleo Associates, Incorporated
SDNHM	San Diego Natural History Museum
SJHTC	San Joaquin Hills Transportation Corridor
UCMP	University of California Museum of Paleontology
USGS	United States Geological Survey

Paleontologic, Chronologic, and Lithologic Terms

K/Ar	potassium/argon radiometric age determination
f.	fauna: an assemblage of one or more taxa of fossil mammals found in more than one geographic and stratigraphic location (e.g., Tedford et al., 1987)
l.f.	local fauna: an assemblage of one or more taxa of fossil mammals found in a geographically and stratigraphically limited location (e.g., Tedford et al., 1987)
Ma	megannum in the radioisotopic time scale
m.y.	millions of years in duration or interval, but not directly tied to the radioisotopic time scale
NALMA	North American land mammal age
S/V	undifferentiated Sespe and Vaqueros formations

GEOGRAPHIC SETTING

With the exception of the San Joaquin Hills, the fossil-producing localities in Orange County discussed in this study are distributed along a northwest-southeast axis in the southwestern foothills of the Santa Ana Mountains in areas underlain by the Sespe Formation and the S/V (fig. 11.2). The fossil-producing area in the San Joaquin Hills also is underlain by the S/V. Most of the fossils were collected during grading associated with major construction projects, and most of these fossil-producing areas now are covered by man-made structures, including a housing development (Parkridge) and several roadways (ETC, FTC Oso Segment, SJHTC), or are buried (Santiago Canyon and Frank R. Bowerman landfills). Future construction in Orange County undoubtedly will lead to the recovery of additional fossil specimens.

The fossils from the Santa Monica Mountains were recovered from roadcuts along Piuma and Stunt roads. The fossils from the Simi Valley area were recovered in a housing development in the hills at the southwestern corner of the valley.

GEOLOGIC AND PALEONTOLOGIC SETTING

The Santa Ana Mountains and the San Joaquin Hills are at the northern end of the Peninsular Ranges Province, in which major geologic structures are oriented in a northwesterly direction (fig. 11.1). The Santa Ana Mountains are a northwesterly-plunging anticline that exposes primarily marine sedimentary strata ranging in age from Jurassic to Pleistocene (Morton and Miller, 1981;

Schoellhamer et al., 1981). The core of the mountain range is composed of upper Jurassic to early Cretaceous volcanic and associated intrusive rocks (Santiago Peak Volcanics) that intrude and overlie a sequence of metamorphosed middle Jurassic marine fore-arc basin strata (Bedford Canyon Formation). The Cretaceous through Pliocene interval is represented by a discontinuous succession of near-shore marine strata with some intervening continental strata and submarine lava flows. Formational boundaries often are distinct, representing depositional hiatuses reflecting marine transgressive and regressive events mostly associated with tectonic activity along the western margin of the North American plate and the eastern margins of adjacent oceanic plates (Belyea, 1984). The Santa Ana Mountains have been uplifted and folded by offset along the Elsinore and Cristianitos faults and a number of smaller unnamed faults. Extensive faulting has made it particularly difficult to correlate fossil-bearing strata, even between nearby localities.

The Santa Monica Mountains are one of a series of east-west-trending ranges in which complex faulting has uplifted a discontinuous sequence of primarily marine sedimentary formations ranging in age from late Cretaceous to late Miocene (Yerkes and Campbell, 1979, 1980; Dibblee, 1993). The core of the mountains contains older (Jurassic) plutonic and metamorphic rocks. Significant basaltic and andesitic flows (Conejo and Zuma volcanics) are found in the middle Miocene part of the sequence. The Conejo Volcanics have been radiometrically dated at 16.0–13.4 Ma (Turner, 1970; Turner and Campbell, 1979). Minor volcanic ashes are found in the Sespe Formation but have not yielded reliable radiometric age determinations.

Sedimentary strata underlying the Simi Hills and adjacent hills along the southern margin of the Simi Valley are part of a fault-bounded crustal block (Simi uplift) now bounded to the north by the reverse-offset Simi Fault (Squires, 1983; Dibblee, 1992). The Simi Hills contain a discontinuous sequence of formations similar to that in the Santa Monica Mountains.

Although the Santa Ana Mountains contain a succession of formations, for the purposes of this study only the S/V, the underlying Santiago Formation (lower to middle Eocene), and the overlying Topanga Formation (lower to middle Miocene) are discussed.

Santiago Formation

The lower to middle Eocene Santiago Formation, up to approximately 900 m thick, conformably underlies the nonmarine basal conglomerate of the middle Eocene to lower Miocene S/V. In most of the northern Santa Ana Mountains of Orange County, the lower part of the Santiago Formation is marine in origin, and the upper part is nonmarine (Schoellhamer et al., 1981). However, near the southwestern corner of the northern Santa Ana Mountains, the entire formation is nonmarine in origin. The formation is composed mostly of coarser-grained strata, including yellowish conglomerate beds up to 75 m thick and buff to yellow or gray, massive, fine- to coarse-grained concretionary sandstone layers interbedded with some finer-grained strata, including gray to black sandy siltstone and fine-grained sandstone layers (Schoellhamer et al., 1981).

The lower part of the Santiago Formation has yielded land plants and marine mollusks, crustaceans, and bony fishes. The presence of the gastropods *Turritella uvasana applinae*? and *Turritella buwaldana buwaldana*? indicates that the invertebrate assemblages are assignable to the Domengine Provincial Marine Molluscan Stage (later Ypresian to earlier Lutetian = early to early middle Eocene) (Dickerson, 1914; Woodring and Popenoe, 1945; Roth, 1958; Killen, 1961; Schoellhamer et al., 1981; Sundberg, 1984; see also Saul, 1983; Squires, 1988). The upper part of the Santiago Formation also has yielded land plants (Roth, 1958; Killen, 1961; Fife, 1972; Morton, 1974).

In coastal northwestern San Diego County, the upper part (Members B and C) of the Santiago Formation has yielded marine mollusks, marine vertebrates, and early Uintan to latest Uintan or Duchesnean continental vertebrates. Calcareous nannofossils recovered from Member C are assignable to Calcareous Nannoplankton Zone CP14a (later Lutetian to earlier Bartonian = middle Eocene) (Golz, 1976; Chiment, 1977; Golz and Lillegraven, 1977; Kelly, 1990; Bukry, 1991; Walsh, 1991, 1996; Colbert, 1993).

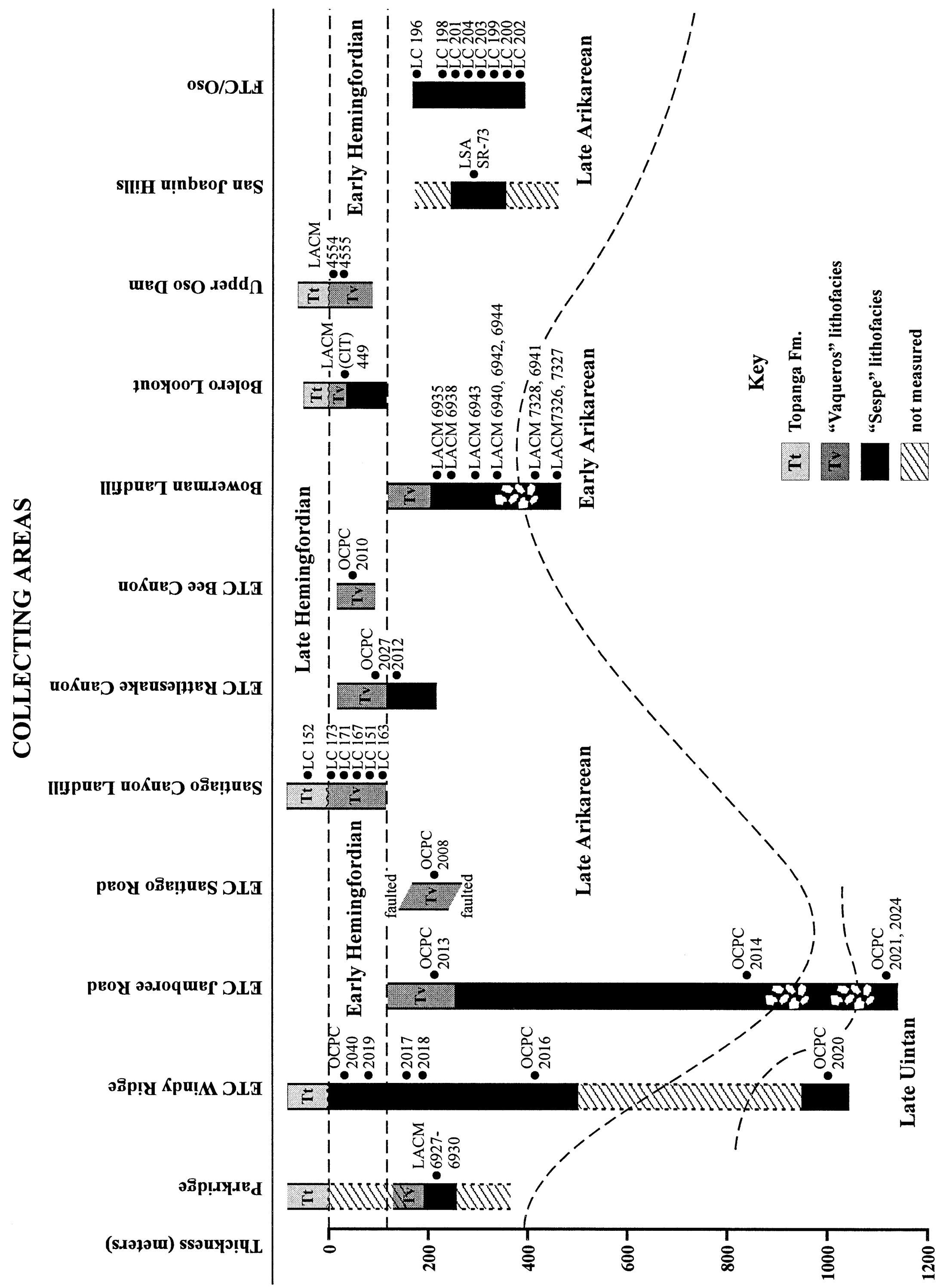
Sespe and Vaqueros Formations, Undifferentiated

Nearly all interbedded variegated redbed sequences in the Santa Ana Mountains and much of coastal southern California generally are referred to as the Sespe Formation or as the undifferentiated Sespe and Vaqueros formations (Howard, 1988; Lander, 1994a). This is a common practice, even though the Sespe Formation was defined by Watts (1897) from its type locality along Sespe Creek, 160 km northwest of the Santa Ana Mountains, and the Vaqueros Sandstone was defined by Hamlin (1904) from its type locality in the Coast Ranges of central California, 420 km northwest of the Santa Ana Mountains.

Although greenish-gray marine sandstone strata referred to the Vaqueros Formation are restricted to the upper part of the S/V in the Santa Ana Mountains, and variegated and red sandstone/mudstone sequences referred to the Sespe Formation are found throughout the S/V, the two lithofacies interdigitate to form a transitional zone at some localities (Schoellhamer et al., 1981). Geologic maps of the northern Santa Ana Mountains (Rogers, 1965; Schoellhamer et al., 1981) do not differentiate the Sespe and Vaqueros formations. However, Belyea (1984) and Belyea and Minch (1989) applied a lithofacies analysis to determine relationships, concluding that the Vaqueros Formation represents a transgressive sequence of clastic marine shoreline deposits that characterize the final phases of S/V deposition in the northern Peninsular Ranges. The S/V includes a transitional zone in which continental ‘‘Sespe’’ strata and marine ‘‘Vaqueros’’ strata interdigitate extensively. The S/V, up to approximately 1,200 m thick, conformably overlies the lower to middle Eocene Santiago Formation and is separated from the overlying lower to middle Miocene undifferentiated Topanga Formation by a slight erosional unconformity.

The lower part of the S/V is a conglomerate sequence up to approximately 100 m thick, presumably entirely of nonmarine origin. The remainder of the S/V is a sequence of reddish, gray, buff, tan, pinkish- to reddish-gray, red, reddish-brown, greenish-gray, yellowish-gray, and yellow to white, poorly bedded, coarse-grained to conglomeratic sandstone layers with reddish-brown clayey sandstone layers and conglomerate lenses. The lower part of this dominantly coarse-grained sequence contains numerous red sandy claystone paleosols, and the upper part of the sequence contains thin interbeds of red and green sandy siltstone.

Marine invertebrates characteristic of the early Miocene Vaqueros Provincial Marine Molluscan Stage are common in the ‘‘Vaqueros’’ (marine) lithofacies (Schoellhamer et al., 1981), and continental vertebrates ranging in age from late middle Eocene (late Uintan) to late early Miocene (early Hemingfordian) now are well documented as occurring in the ‘‘Sespe’’ (continental) lithofacies. Along the southwestern slope of the northern Santa Ana Mountains, the upper part of the S/V is interbedded with thin greenish-gray to white, well-bedded sandstone and silty sandstone layers of marine origin that grade laterally to the southwest into finer-grained deeper-water marine strata (Schoellhamer et al., 1981; Belyea and Minch, 1989). These strata and laterally equivalent strata in the San Joaquin Hills have yielded marine invertebrates including *Turritella inezana*, ‘‘*Macrochlamis*’’ *magnolia magnolia*, *Vertipecten bowersi*, and *Lyropecten miguelensis* that are assignable to the Lower and Upper Vaqueros Provincial Marine Molluscan Stages (early? Oligocene to early Miocene; Schoellhamer et al., 1981; Belyea and Minch, 1989). Strata of the S/V and of the Sespe Formation in the southern Santa Ana Mountains have yielded continental vertebrates assignable to the late Uintan, early and late Arikareean, and early Hemingfordian NALMAs. Marine vertebrates (sharks, rays, bony fishes, turtles, whales, and porpoises) also have been recovered from the redbeds in the ‘‘Sespe’’ lithofacies, and continental vertebrates also have been recovered from marine strata in the ‘‘Vaqueros’’ lithofacies (Savage, 1972; Raschke, 1984a, 1988; Tedford et al., 1985, 1987, 1996; Belyea and Minch, 1989; Lander, 1994a, 1997; Lucas et al., 1997).


COLLECTING AREAS
Thickness (meters)
0
200
400
600
800
1000
1200
Parkridge
ETC Windy Ridge
ETC Jamboree Road
ETC Santiago Road
Santiago Canyon Landfill
ETC Rattlesnake Canyon
ETC Bee Canyon
Bowerman Landfill
Bolero Lookout
Upper Oso Dam
San Joaquin Hills
ETC/Oso
Early Hemingfordian
Late Hemingfordian
Late Arikareean
Early Arikareean
Late Uintan
faulted
Key
Topanga Fm.
"Vaqueros" lithofacies
"Sespe" lithofacies
not measured

For the purposes of this study, any sequence composed dominantly of redbeds and lacking marine vertebrates and invertebrates is considered to be continental in origin and to represent the ''Sespe'' lithofacies, and any sequence composed dominantly of greenish-gray strata containing marine vertebrates and invertebrates is considered to be marine in origin and to represent the ''Vaqueros'' lithofacies.

Topanga Formation/Group, Undifferentiated

The Topanga Formation originally was based on a sequence of marine sandstones exposed in an anticline just west of Old Topanga Canyon in the central Santa Monica Mountains (Kew, 1923). Later workers expanded the use of the name ''Topanga'' to include a much thicker, heterogeneous sequence of sedimentary and volcanic rocks in the central and western Santa Monica Mountains (Durrell, 1954). Yerkes and Campbell (1979) elevated the ''Topanga'' to group rank, and defined three formations in the group, including (in ascending order) the Topanga Canyon Formation, Conejo Volcanics, and the Calabasas Formation. Other workers (Dibblee, 1982, 1993) do not recognize the group rank of Yerkes and Campbell (1979), but rather continue to recognize the Topanga Formation as originally defined.

In the northern Santa Ana Mountains, strata mapped as the undifferentiated, lower to middle Miocene marine Topanga Formation, up to 750 m thick, are separated from the underlying S/V by a slight erosional unconformity, and from the overlying middle to upper Miocene La Vida Shale Member of the marine Monterey Formation by an angular unconformity (Schoellhamer et al., 1981). Locally, the base of the Topanga Formation is a 10-m-thick, tan to gray conglomerate interval of fluvial origin. The remainder of the formation consists mostly of light tan to gray, medium- to coarse-grained sandstone layers from 20 cm to 3 m thick and interbedded with fine-grained sandstone and silty sandstone layers. Locally, the upper part of the formation consists of white, tan, greenish-gray, and reddish-brown siltstone, silty sandstone, sandstone, and conglomeratic sandstone layers up to approximately 3 m thick. At least two white vitric tuff layers up to approximately 3 m thick also occur locally.

In the San Joaquin Hills, strata mapped as the Topanga Formation are divided into three stratigraphically superposed members, including the Bommer (lower), Los Trancos (middle), and Paulerino (upper) members (Vedder et al., 1957; Morton and Miller, 1981). However, in the northern Santa Ana Mountains, these members cannot be differentiated.

An andesitic lava flow at the base of the Paulerino Member has yielded a K/Ar date of 15.8 ± 1.3 Ma (Turner, 1970: sample KA 2133; Weigand, 1994; age recalculated using revised decay and abundance constants provided by Dalrymple, 1979).

The Topanga Formation in Orange County has yielded abundant marine benthic foraminifers; marine invertebrates and vertebrates (including some marine birds); a diversity of terrestrial microvertebrates (best represented at locality OCPC 2003, near but not in the measured sections at the Santiago Canyon Landfill; see fig. 11.3), including lizards, boid snakes, a small shrew, *Protospermophilus*, *Nototamias ateles*, *Perognathus*, and *Copemys*; larger land mammals, including ''*Merychippus*'', *Aepycamelus*, and a

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Fig. 11.3. Generalized stratigraphic columnar sections of Sespe Formation and undifferentiated Sespe/Vaqueros formations (S/V) in Santa Ana Mountains and San Joaquin Hills, southern Orange County, California, showing relationships of geologic units and stratigraphic positions of selected continental (primarily microvertebrate) fossil localities. Stratigraphic datum placed at disconformity at base of Topanga Formation. Where stratigraphic datum is lacking, a columnar section is aligned vertically based on faunal similarities with sections containing more complete stratigraphic successions. Fossils in upper part of S/V are early Hemingfordian in age and fossils from overlying Topanga Formation are late Hemingfordian in age, the Vaqueros/Topanga disconformity representing the time interval that includes the boundary between the early and late Hemingfordian.

large paleomerycid; and land plants (Richmond, 1952; Smith, 1960; Schoellhamer et al., 1981; Raschke, 1984a, 1984b; Howard and Barnes, 1987). The presence of Relizian and/or Luisian benthic foraminifers and a gastropod (*Turritella temblorensis*) assignable to the Temblor Provincial Marine Molluscan Stage indicates that the fossil assemblages are early to middle Miocene in age. The presence of *Copemys* and ''*Merychippus*'' suggests that the land mammal assemblages are as old as early late Hemingfordian in age.

STRATIGRAPHY OF FOSSIL-PRODUCING AREAS IN ORANGE COUNTY

A stratigraphic framework of the fossil-producing areas in the Santa Ana Mountains and San Joaquin Hills is shown in figure 11.3. With the exception of the FTC/Oso area, which is in the southern Santa Ana Mountains, and the San Joaquin Hills area, all of the fossil-producing areas described below are in the northern Santa Ana Mountains (see fig. 11.2). As stated above, all but one (Bolero Lookout) of these fossil-producing areas were exposed by grading associated with major construction projects. Neither author has seen all of the areas, but D.P.W. did inspect seven of them. The descriptions of the fossil-bearing sequences are based on personal observations and on mitigation program final reports listed in the appendix.

No laterally continuous marker bed is recognized in the S/V, and direct physical correlation of fossil-bearing strata among the various fossil-producing areas has not been possible on the basis of lithostratigraphic criteria. As stated above, the boundary between the Sespe and Vaqueros formations reflects marine transgressive/regressive events and, therefore, is time-transgressive. Consequently, the disconformity between the S/V and the overlying Topanga Formation is used as a stratigraphic datum in figure 11.3. The lower part of the S/V, with massive conglomerate intervals and paleosols, is entirely continental in origin and is referred to the ''Sespe'' lithofacies. Generally, the upper portion of the S/V is a transitional zone containing interbedded redbed sequences and greenish-gray marine strata. In some sequences, the uppermost part of the S/V, with greenish-gray sandstone and shale layers, is entirely marine in origin and is referred to the ''Vaqueros'' lithofacies in figure 11.3. If both lithofacies and a transitional zone were present in a single section, it would be possible to place fossil occurrences in an accurate stratigraphic context in that section. Unfortunately, no complete S/V section was exposed by grading. The composite stratigraphic framework of the Santa Ana Mountains and the San Joaquin Hills presented in figure 11.3 is based on a somewhat subjective combination of stratigraphic, lithologic, and biostratigraphic data.

PARKRIDGE: The Parkridge parcel is at the northwestern limit of the exposed S/V. The S/V and Topanga formations were exposed by grading. No stratigraphic section was measured, but redbeds of the ''Sespe'' lithofacies and green marine sandstone beds of the ''Vaqueros'' lithofacies are present. Terrestrial megavertebrates (table 11.1) were recovered from four localities (LACM 6927 through 6930) in red claystone beds of the S/V. Fossil recovery was the result of a mitigation program conducted by RMW personnel in support of construction of the Parkridge housing development (appendix: Stadum, 1997).

ETC WINDY RIDGE: The ETC Windy Ridge area is a roadcut that represents the largest excavation from which fossils in the S/V were recovered, with 15,000,000 cubic yards removed over a 2-year period. Grading exposed 320 m of continental redbeds in the S/V and the base of the overlying Topanga Formation. This is the only occurrence where the ''Vaqueros'' lithofacies was not present between the S/V and the Topanga Formation. Four productive microvertebrate localities (in ascending order, OCPC 2016, 2018, 2017, 2019) and a number of larger land mammal specimens were discovered in the S/V. In this area, it is possible to demonstrate the stratigraphic superposition of microvertebrate assemblages of late Arikareean and early Hemingfordian age. The canyon northwest of this area also yielded late Uintan vertebrates near the base of the S/V at OCPC 2020. The fossils were recovered as a result of a mitigation program conducted by PEAI personnel in support of construction of the ETC toll road.

ETC JAMBOREE ROAD: The Jamboree Road area is a large roadcut that contains the thickest measured section (1,077 m) of the S/V. Donohoo and Prothero (1999) documented the paleomagnetic stratigraphy in the upper part of this section. Two late Uintan microvertebrate localities (OCPC 2012, 2024) are present near the bottom of the section below a massive conglomeratic interval. Along with the assemblage in the ETC Windy Ridge area, this assemblage represents the first record of Eocene land mammals in the S/V and includes typical late Uintan taxa such as *Peratherium*, *Sespedectes*, *Dyseolemur*, *Microparamys*, *Griphomys*, and *Simimys*. The conglomeratic interval is overlain by 500 m of continental redbeds containing one productive microvertebrate locality (OCPC 2014) near the base of the redbed interval. The redbed interval, in turn, is overlain by 200 m of interbedded green and gray to nearly white marine sandstone and shale layers that have yielded marine invertebrates and vertebrates and, at one locality (OCPC 2013), a few continental microvertebrates. The fossils were recovered as a result of the mitigation program conducted by PEAI personnel in support of construction of the ETC toll road.

ETC SANTIAGO ROAD: The most productive continental microvertebrate locality (OCPC 2008) in the S/V occurred in a green and gray clayey siltstone bed in a roadcut in a small, highly faulted exposure along Santiago Road. Unfortunately, faulting precluded measuring a stratigraphic section. The lithology of the fossil-bearing interval is typical of the ‘‘Vaqueros’’ lithofacies, although only a few shark teeth were associated with the microvertebrates. The fossils were recovered as a result of the mitigation program conducted by PEAI personnel in support of construction of the ETC toll road.

SANTIAGO CANYON LANDFILL: The Santiago Canyon Landfill is a large, ongoing excavation that has yielded 16 fossil localities in a 55-m interval in the uppermost part of the S/V. The fossil-bearing interval is composed of interbedded dark red sandstone layers and paleosols and green and yellow sandstone layers that are overlain by marine sandstone beds of the Topanga Formation. Although the S/V appears to be mostly continental in origin, many beds yielded shark and ray teeth, indicating a close proximity to a marine environment. The Topanga Formation yielded the mouse *Copemys* in association with marine vertebrates (sharks, rays, and bony fishes) at LC 152. The fossils were recovered as a result of mitigation programs conducted by PEAI and RMW personnel in support of grading associated with the landfill operation (Lander, 1994a; Raschke, 1997b; appendix: Whistler, 1993, 1994a, 1997a).

ETC RATTLESNAKE CANYON: The ETC Rattlesnake Canyon occurrence is a roadcut along the ETC where the S/V consists of a 100-m sequence that is composed of red continental sandstone layers and paleosols overlain by a 47-m interval of fine-grained green and olive sandstone and siltstone layers containing numerous marine vertebrates (sharks, rays, and bony fishes) and invertebrates. The redbed interval contains one productive microvertebrate locality (OCPC 2012), but the overlying marine interval yielded only four rodent teeth (at OCPC 2027). The fossils were recovered as a result of the mitigation program conducted by PEAI personnel in support of construction of the ETC toll road.

ETC BEE CANYON: The S/V in the ETC Bee Canyon occurrence is a roadcut along the ETC with a red silty sandstone interval containing one fossil locality (OCPC 2010) that yielded abundant marine vertebrates and a diverse continental microvertebrate assemblage. Although reddish in color, the occurrence of marine vertebrates indicates that the fossil-bearing strata are marine in origin. The fossils were recovered as a result of the mitigation program conducted by PEAI personnel in support of construction of the ETC toll road.

BOWERMAN LANDFILL: The Frank R. Bowerman Landfill is a large, ongoing excavation (5 km^2) that has buried several canyons mostly underlain by the S/V. Unfortunately, the stratigraphy of the area is difficult to reconstruct because of extensive faulting and massive landsliding. However, four measured sections with a composite thickness of 190 m have allowed the placement of the more important localities in a local stratigraphic

TABLE 11.1

Composite Vertebrate Faunal Lists: Sespe Formation and Undifferentiated Sespe and Vaqueros Formations

Located in Santa Ana Mountains and San Joaquin Hills, southern Orange County, California, and other collecting areas in southern and south-central California. See figures 11.2 and 11.3 for locations and stratigraphic ranges in southern Orange County. Late Uintan Basal Orange County S/V fauna not included. See text and figure 11.5 for information on localities outside Orange County. U. = upper; L. = lower; LA Co. = Los Angeles County; Can. = Canyon; l.f. = local fauna; Fm. = formation.

Taxa/Faunas	Parkridge l.f.	ETC L. Windy Ridge l.f.	EFC U. Windy Ridge l.f.	ETC Jamboree Road l.f.	ETC Santiago Road l.f.	Santiago Can. Landfill l.f.	ETC L. Rattlesnake Can. l.f.	ETC U. Rattlesnake Can. l.f.	ETC Bee Canyon l.f.	L. Bowerman l.f.	U. Bowerman l.f.	Bolero Lookout l.f.	U. Oso Dam l.f.	San Joaquin Hills l.f.	FTC/Oso l.f.	Blakeley l.f.	Alamos Canyon l.f.	Piuma Road l.f.	Tick Canyon l.f.	Boron l.f.	Orange Co. Topanga Fm.	LA Co. Topanga Fm.	Vedder l.f.
Sharks/rays	0	0	0	x	x	x	0	x	x	0	x	x	x	x	x	0	x	0	0	0	x	0	0
Teleostei	0	0	0	x	0	x	0	x	x	0	0	0	x	0	0	0	0	0	0	0	0	0	0
Reptilia																							
Chelonia	0	x	0	0	0	x	0	0	0	0	0	x	x	0	0	0	0	0	0	0	0	0	0
Gerrhonotus sp.	0	0	0	0	0	x	0	0	0	0	x	0	0	0	x	0	0	0	0	0	0	0	0
Glyptosaurinae?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0
Parasauromalus sp.	0	0	0	0	0	0	0	0	x	0	x	0	0	0	x	0	0	0	0	x	0	0	0
Xantusia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	x	0	0	0
Boidae indet.	0	0	0	0	0	x	0	0	0	0	x	0	x	0	x	0	0	0	0	x	0	0	0
Colubridae indet.	0	0	0	0	0	x	0	0	0	0	x	0	x	0	x	0	0	0	0	x	0	0	0
Mammalia																							
Marsupialia																							
Herpetotherium sp.	0	0	0	x	0	x	0	0	0	0	x	0	0	x	x	0	0	0	0	0	0	0	0
Insectivora																							
Erinaceidae indet.	0	0	0	0	0	x	0	0	x	0	x	0	x	0	x	x	0	0	0	0	0	0	x
Heterosoricidae indet.	0	x	0	0	x	x	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0
Scalopoides sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x
Limnoecus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x
Carnivora																							
Cynelos sp.	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mustelidae indet.	x	x	0	0	0	0	0	0	0	0	x	0	0	x	x	0	0	0	0	0	0	0	0
Cynarctoides gawnae	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phlaocyon spp.	0	x	0	0	0	x	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0
Leptocyon? sp.	0	0	0	0	0	0	0	0	0	0	x	0	0	0	x	0	0	0	0	0	0	0	0
Felidae indet.	0	0	0	0	0	x	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0
Lagomorpha																							
Cuyamalagus dawsoni	0	x	0	x	x	x	0	0	0	0	x	0	0	x	0	0	0	x	0	0	0	0	x
Gripholagomys? sp.	0	x	0	0	x	0	x	0	0	0	x	0	0	0	x	0	0	0	0	0	0	0	0
Archaeolagus sp.	0	0	0	0	0	x	0	0	0	0	0	0	x	0	0	x	x	0	x	x	0	0	x
Hypolagus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x
Rodentia																							
Nototamias spp.	0	x	x	0	0	x	0	0	x	0	0	0	0	0	x	0	0	0	0	0	0	0	x
Miospermophilus spp.	0	x	x	x	x	x	0	0	x	x	x	0	0	0	x	x	0	0	0	0	0	0	x
Petauristodon? sp.	0	0	0	0	x	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudotheridomys cuyamaensis	0	0	0	0	x	x	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	x
Pseudotheridomys sp. (large)	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heliscomys sp.	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0
Cupidinimus near *C. lindsayi*	0	0	0	0	0	x	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 11.1
(*Continued*)

Taxa/Faunas	Parkridge l.f.	ETC L. Windy Ridge l.f.	EFC U. Windy Ridge l.f.	ETC Jamboree Road l.f.	ETC Santiago Road l.f.	Santiago Can. Landfill l.f.	ETC L. Rattlesnake Can. l.f.	ETC U. Rattlesnake Can. l.f.	ETC Bee Canyon l.f.	L. Bowerman Landfill l.f.	U. Bowerman Landfill l.f.	Bolero Lookout l.f.	U. Oso Dam l.f.	San Joaquin Hills l.f.	FTC/Oso l.f.	Blakeley l.f.	Alamos Canyon l.f.	Piuma Road l.f.	Tick Canyon l.f.	Boron l.f.	Orange Co. Topanga Fm.	LA Co. Topanga Fm.	Vedder l.f.
Rodentia (*continued*)																							
Cupidinimus boronensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0
Proheteromys spp.	0	0	0	x	0	x	x	x	x	x	x	0	0	x	x	0	0	0	0	0	0	0	x
Trogomys rupinimenthae	0	x	x	x	x	x	x	x	x	0	x	0	x	x	x	0	0	x	x	x	0	x	x
Schizodontomys sp.	0	x	x	0	x	x	0	x	0	x	x	0	0	x	x	0	0	0	0	0	0	0	0
Leidymys nematodon	0	0	0	x	x	0	x	0	0	x	x	0	0	x	x	x	x	0	0	0	0	0	0
Leidymys sp. (small)	0	0	0	0	x	x	0	0	0	0	0	0	x	0	x	0	0	0	0	0	0	0	0
Yatkolamys sp.	0	0	x	0	0	x	0	x	x	0	0	0	0	0	0	0	0	x	0	0	0	0	0
Copemys sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0
Perissodactyla																							
Menoceras barbouri	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
?*Kalobatippus clarencei*	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parapliohippis carrizoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	x	0
Merychippus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0
Parahippus pawniensis	0	0	0	0	0	x	0	0	0	0	0	x	0	0	0	0	0	0	x	0	0	0	0
Artiodactyla																							
Daeodon hollandi	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0
?*Cynorca* sp.	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sespia nitida	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0
Merychyus elegans	0	0	x	0	0	x	0	0	0	0	x	0	x	0	x	0	0	0	x	x	0	0	0
?*Merychyus* sp.	x	x	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	x
Michenia agatensis	x	x	x	0	0	x	0	0	x	0	x	x	x	x	x	0	0	0	0	0	0	0	0
Tanymykter? sp.	x	x	x	0	0	x	0	0	0	0	x	0	0	x	0	0	0	0	0	x	0	0	0
Miolabis californicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0
Aletomeryx occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0
Nanotragulus loomisi?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	x	0	0	0	0	0	0
Nanotragulus ordinatus?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0
?*Machaeromeryx tragulus*	0	x	0	0	0	x	0	0	0	0	x	0	0	x	0	0	0	0	0	0	0	0	0
?*Pseudoblastomeryx advena*	0	x	0	0	0	x	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0

framework. The section shown in figure 11.3 is a composite of three of these sections. All of the localities occurred in the "Sespe" lithofacies, but several localities yielded one or two teeth of the shark *Carcharhinus*. *Carcharhinus* is known to swim into freshwater habitats and, therefore, its presence in the S/V does not necessarily indicate a marine environment. This area is one of only two in Orange County that has yielded an early Arikareean land mammal assemblage. Hundreds of fossil localities, including eight that yielded identifiable microvertebrates, were discovered as a result of a mitigation program conducted by RMW personnel in support of grading a landfill (Raschke, 1997a, 1997b, 1997c, 1998; appendix: Whistler, 1994b, 1994c, 1996a, 1996b, 1997a).

BOLERO LOOKOUT: The stratigraphy of the S/V at Bolero Lookout has been described in detail by Belyea and Minch (1989) and Lucas et al. (1997). The fossils from this area were recovered at the top of a sequence of variegated redbeds and green sandstone beds

(S/V) that underlie a 20-m green marine sandstone interval (''Vaqueros'' lithofacies) that, in turn, is overlain by the Topanga Formation.

UPPER OSO DAM: The S/V in the Upper Oso Dam area consists of 34 m of interbedded greenish marine clayey siltstone and thin and more massive, cross-bedded sandstone layers generally referable to the ''Vaqueros'' lithofacies overlain by 60 m of strata assigned to the Topanga Formation. Continental vertebrates were recovered at two fossil localities within the S/V (LACM 4554, 4555) stratigraphically separated by 6.8 m. The lower locality (LACM 4555) yielded a diversity of marine vertebrates and fossil rodents, and the upper locality yielded only continental vertebrates (Raschke, 1984a, 1984b). *Copemys*, *Aepycamelus*, a small species of ''*Merychippus*'', and a large paleomerycid were recovered from the overlying Topanga Formation. Fossils recovered by LACM personnel from the S/V in the Upper Oso Dam area represented the first significant discovery of continental vertebrates in the ''Vaqueros'' lithofacies (Raschke, 1984a, 1984b).

SAN JOAQUIN HILLS: Fossils from the San Joaquin Hills were recovered in a roadcut exposed during construction of the SJHTC. The fossil locality in the San Joaquin Hills occurred in continental redbed sequences typical of the S/V (Conkling, 1996) and the ''Sespe'' lithofacies. At least 170 m of section were exposed in the vicinity of the fossil occurrences. Conkling et al. (appendix: 1997) assigned the fossil assemblages from these localities to the San Joaquin Hills l.f. This area is highly faulted and, because of the lack of marker beds, it was not possible to correlate strata between adjacent roadcuts. The fossils were recovered as a result of a mitigation program conducted by LSA personnel in support of construction of the SJHTC toll road (see appendix).

FTC/OSO: Fossils from the southern Santa Ana Mountains east of Plano Trabuco were recovered from roadcuts along the Oso segment of the FTC. The fossil localities occurred in a 170-m succession of massive, medium- to coarse-grained, nearly white sandstone beds interbedded with thin red siltstone beds. The fossil-bearing interval is mapped as the Sespe Formation by Morton and Miller (1981) and is overlain by the Vaqueros Formation. However, marine vertebrates (sharks) were recovered from some of the redbeds. Fossils were recovered as a result of a mitigation program conducted by PEAI personnel in support of construction of the Oso Segment of the FTC toll road (appendix: Lander and Whistler, 1999).

STRATIGRAPHY OF FOSSIL-PRODUCING AREAS IN THE SANTA MONICA MOUNTAINS AND SIMI VALLEY

Land mammal assemblages from two new localities in the Sespe Formation of Los Angeles and Ventura counties are particularly important for implications regarding biostratigraphic correlations with the Orange County assemblages (table 11.1).

BLAKELEY: The fossils from the Blakeley Western parcel in Ventura County were recovered in a housing development in the hills above the southwestern corner of Simi Valley. Grading exposed stratigraphically superposed rock units, including (in ascending order) a 60-m interval of conglomeratic sandstone with thin interbeds of reddish-brown siltstone layers in the upper member of the Sespe Formation, a 3–4-m interval of light brown cobble conglomerate and light orange pebbly sandstone in the marine Lower Topanga Formation, a 6–7-m interval of brown amygdaloidal basalt representing a previously unrecognized tongue at the base of the Conejo Volcanics, and an 8-m interval of light orange to very light gray, fine-grained sandstone in the marine Middle Topanga Formation, all capped by the main body of the Conejo Volcanics. Fossil microvertebrates and a distinctive hypertragulid artiodactyl were recovered from the Sespe Formation, and age-diagnostic marine invertebrates were recovered from the Lower Topanga Formation. On the basis of paleontologic data, the fossil-bearing interval in the Sespe Formation, incorrectly mapped as being in the lower member by Squires (1983), actually is in the upper member, immediately below an unconformity with the Lower Topanga Formation. The fossils constitute the Blakeley l.f., a correlative of the Alamos Canyon l.f., which occurs in the transitional zone between the Sespe and Vaqueros formations along the northern margin of Simi Valley (Lander, 1983, 1994a). Fossils from the Blakeley Western parcel were recovered as a result of a mitigation program conducted by PEAI personnel in support of construction of a housing development (appendix: Lander, 1999).

PIUMA ROAD: Fossils from Piuma Road were recovered from a roadcut immediately southwest of Saddle Peak along the crest of the western Santa Monica Mountains in Los Angeles County. The thick section in this area consists of 440 m of the Piuma (upper) Member (Yerkes and Campbell, 1979, 1980; Lander et al., 2001) of the Sespe Formation overlain by the marine Saddle Peak (lower) Member of the Topanga Canyon Formation of the Topanga Group (mapped as Lower Topanga Formation by Dibblee, 1993). The 5-m ''Saddle Peak'' or Carbon Canyon Tongue of the Vaqueros Formation, 98 m above the base of the Piuma Member, separates the lower and upper parts of the Piuma Member. Two stratigraphically superposed fossil-bearing intervals are recognized in the Piuma Member. The Lower Piuma Road l.f. occurs in red to reddish brown sandy siltstones in the lower 20 m of the Piuma Member. The Upper Piuma Road l.f. is in a 3-m red claystone sequence in the upper 9 m of the Piuma Member of the Sespe Formation (Lander et al., 2001). Other vertebrate localities in the Piuma Member along Piuma Road have yielded additional land mammals, possibly including a blastomerycine. The only other vertebrate locality (UCMP V-6104) in the Piuma Member yielded a camel southwest of Saddle Peak along Malibu Canyon Road.

The Carbon Canyon Tongue of the Vaqueros Formation contains marine vertebrates (rays) and mollusks, including the gastropod *Turritella inezana bicarina*, which is assignable to the lower Vaqueros Provincial Marine Molluscan Stage (Lander et al., 2001; see Loel and Corey, 1932). The lower 25 m of the Saddle Peak Member of the overlying Topanga Canyon Formation contain marine mollusks, including the pelecypod *Vertipecten bowersi*, which is assignable to the Upper Vaqueros Provincial Marine Molluscan Stage (Smith, 1991; Lander et al., 2001). The Fernwood (middle) Member (Yerkes and Campbell, 1979, 1980; mapped as Lower Topanga Formation by Dibblee, 1993; assigned to Fernwood Tongue of Sespe Formation by Fritsche, 1993) of the Topanga Canyon Formation at LACM 4512 has yielded land mammals, including the dominantly early late Hemingfordian horse *Parapliohippus carrizoensis* (Dougherty, 1940) (Quinn, 1987; Kelly and Lander, 1988; Lander et al., 2001) and the Hemingfordian rodent *Proheteromys sulculus* (Wilson, 1960; Lander et al., 2001; see Lindsay, 1974). The Conejo Volcanics, which overlie the Topanga Canyon Formation, have yielded a K/Ar date of 16.0 Ma (Turner and Campbell, 1979, sample DT-81D1; Weigand and Savage, 1993; see Berggren et al., 1995; age converted using decay and abundance constants provided by Dalrymple, 1979). Fossiliferous rock samples were collected specifically for this study.

TAXONOMY

The purpose of this study is to provide a biostratigraphic overview of the Miocene assemblages of the S/V, not to provide detailed taxonomic descriptions of their respective taxa. For the purposes of this paper, a particular specimen of uncertain taxonomic allocation has been referred to the most similar previously described taxon. New taxa certainly are present in the S/V assemblages, and future taxonomic analyses will refine the biostratigraphic framework presented in this paper.

Table 11.1 is a composite faunal list for the S/V in the collecting areas of Orange County and other collecting areas discussed below. The collecting area names are keyed to those shown in figures 11.2 and 11.3. Many of these areas have stratigraphically superposed local faunas, which are listed as ''upper'' and ''lower'' in table 11.1. Table 11.2 provides a more detailed breakdown of the taxa from the taxonomically more diverse fossil localities that have been combined to characterize the faunas/local faunas listed in table 11.1. Often, larger vertebrate fossil specimens are found as single or isolated occurrences and, therefore, their localities are not included in table 11.2. In addition to some continental vertebrates, the ''Vaque-

TABLE 11.2

Composition of Fossil Land Mammal Assemblages from Specific Localities Used to Characterize New Local Faunas: Sespe Formation and Undifferentiated Sespe and Vaqueros Formations

Located in Santa Ana Mountains and San Joaquin Hills, southern Orange County, California. For a single local fauna characterized by assemblages from multiple localities, fossil localities are listed in order of ascending stratigraphic position. See text and figure 11.3 for more detailed data on stratigraphic superposition of specific fossils localities. Rdg. = ridge; Cyn. = canyon; L. = lower; U. = upper.

Local Fauna	Parkridge	ETC L.Windy Rdg.	ETC L.Windy Rdg.	ETC L.Windy Rdg.	ETC L.Windy Rdg.	ETC Jamboree Rd.	ETC Jamboree Rd.	ETC Santiago Rd.	Santiago Cyn. Landfill	Santiago Cyn. Landfill	Santiago Cyn. Landfill	L. ETC Rattlesnake Cyn.	U. ETC Rattlesnake Cyn.	ETC Bee Can.	L. Bowerman Landfill	L. Bowerman Landfill	U. Bowerman Landfill	U. Bowerman Landfill	U. Bowerman Landfill	U. Bowerman Landfill	Bolero Lookout	U. Oso Dam	San Joaquin Hills	FTC OSO	FTC OSO	FTC OSO	FTC OSO
Taxa/Localities	LACM 6927-30	OCPC 2016	OCPC 2018	OCPC 2017	OCPC 2019, 2040	OCPC 2014	OCPC 2013	OCPC 2008	LC 151, 162-3, 194	LC 164-168	LC 169-174	OCPC 2012	OCPC 2027	OCPC 2010	LACM 7326/7327	LACM 7328/7341	LACM 6940/6942/6944	LACM 6943	LACM 6938	LACM 9635	LACM(CIT) 449	LACM 4555/4554	LSA SR-73	LC 202, 205	LC 199	LC 204	LC 196, 198, 201
Marsupialia																											
Herpetotherium sp.	0	0	0	0	0	0	x	0	x	x	0	0	0	0	0	0	x	0	0	x	0	0	0	x	0	0	x
Insectivora																											
Erinaceidae	0	0	0	x	0	0	0	0	0	x	0	0	x	0	0	0	0	x	0	0	0	0	0	0	0	0	0
Heterosoricidae	0	x	0	0	0	0	0	x	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	x
Carnivora																											
Cynelos sp.	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cynarctoides gawnae	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phlaocyon spp.	0	0	0	0	x	0	0	0	0	x	x	0	0	0	0	0	0	x	0	0	0	0	0	x	0	0	0
cf. *Leptocyon* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	x	0	0	0
Lagomorpha																											
Cuyamalagus dawsoni	0	0	0	x	x	0	x	x	x	x	x	x	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0
?*Gripholagomys* sp.	0	0	0	x	0	0	0	x	0	0	0	0	0	0	0	0	x	x	x	0	0	0	0	x	0	x	0
Archaeolagus sp.	0	0	0	0	0	0	0	0	x	0	x	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0
Rodentia																											
Nototamias spp.	0	x	x	x	x	0	0	0	x	x	x	0	0	x	0	x	0	0	0	x	0	0	0	0	0	0	0
Miospermophilus spp.	0	0	x	x	x	0	x	x	x	x	x	0	0	0	0	x	0	0	x	x	0	0	0	x	0	0	x
?*Petauristodon* sp.	0	0	0	0	0	0	0	x	0	x	x	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	x
Pseudotheridomys cuyamaensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudotheridomys sp. (large)	0	0	0	0	0	0	0	0	x	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heliscomys sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0
Cupidinimus near *C. lindsayi*	0	0	0	0	0	0	0	0	x	0	x	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0
Proheteromys spp.	0	0	0	0	0	x	0	0	0	0	0	x	x	x	0	x	0	0	x	0	0	0	x	0	0	0	0
Schizodontomys sp.	0	x	x	0	0	x	0	x	0	0	0	x	x	x	0	0	x	x	x	x	0	0	x	x	x	x	x
Leidymys nematodon	0	0	0	0	0	0	x	x	0	0	0	x	0	0	0	x	x	x	x	x	0	0	x	x	x	0	x
Leidymys sp. (small)	0	0	0	0	0	0	0	x	x	x	x	0	0	0	0	0	0	0	0	0	0	x	0	0	0	x	0
Yatkolamys sp.	0	0	0	0	x	0	0	0	x	x	x	0	x	x	0	0	0	0	0	0	0	0	0	0	0	0	0
Perissodactyla																											
Menoceras barbouri	0	0	0	0	0	0	0	0	x	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
?*Kalobatippus clarencei*	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Merychippus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parahippus pawniensis	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0

TABLE 11.2
(*Continued*)

Local Fauna	Parkridge	ETC L. Windy Rdg.	ETC L. Windy Rdg.	ETC L. Windy Rdg.	ETC L. Windy Rdg.	ETC Jamboree Rd.	ETC Jamboree Rd.	ETC Santiago Rd.	Santiago Cyn. Landfill	Santiago Cyn. Landfill	Santiago Cyn. Landfill	L. ETC Rattlesnake Cyn.	U. ETC Rattlesnake Cyn.	ETC Bee Canyon	L. Bowerman Landfill	L. Bowerman Landfill	U. Bowerman Landfill	U. Bowerman Landfill	U. Bowerman Landfill	U. Bowerman Landfill	Bolero Lookout	U. Oso Dam	San Joaquin Hills	FTC OSO	FTC OSO	FTC OSO	FTC OSO
Taxa/Localities	LACM 6927-30	OCPC 2016	OCPC 2018	OCPC 2017	OCPC 2019, 2040	OCPC 2014	OCPC 2013	OCPC 2008	LC 151, 162-3, 194	LC 164-168	LC 169-174	OCPC 2012	OCPC 2027	OCPC 2010	LACM 7326/7327	LACM 7328/7341	LACM 6940/6942/6944	LACM 6943	LACM 6938	LACM 9635	LACM(CIT) 449	LACM 4555/4554	LSA SR-73	LC 202, 205	LC 199	LC 204	LC 196, 198, 201
Artiodactyla																											
Daeodon hollandi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
?*Cynorca* sp.	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sespia nitida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	x	0	0	0	0	0	0	0	0	0	0	0
Merychyus elegans	0	0	0	0	0	0	0	0	x	x	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0
?*Merychyus* sp.	x	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Michenia agatensis	x	0	0	0	0	0	0	0	x	x	0	0	0	0	0	0	0	0	0	0	x	0	0	x	0	0	0
?*Tanymykter* sp.	x	x	0	0	0	0	0	0	x	x	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nanotragulus ordinatus?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0
?*Machaeromeryx tragulus*	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	x	0	0	0	0
?*Pseudoblastomeryx advena*	0	0	x	0	0	0	0	0	x	x	x	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0

ros'' lithofacies has yielded a diversity of marine vertebrates, including sharks, rays, bony fishes, turtles, crocodiles, desmostylians, mysticetes, odontocetes, and pinnipeds, whose biostratigraphic relations are beyond the scope of this paper.

Marsupials are represented in the S/V assemblages by a small didelphid resembling the didelphid from the Upper Rosebud Beds at South Dakota School of Mines and Geology Black Bear Quarry II in southwestern South Dakota and now referred to *Herpetotherium* (see Green and Martin, 1976; Korth, 1994a). The largest sample of this taxon is from locality LC 201 in the FTC/Oso area.

Shrews are rare in the S/V assemblages. A few molars and, in particular, a number of I2s with a bifid crown are comparable in size and dental morphology to those of *Heterosorex roperi* (Wilson, 1960) from the early Hemingfordian Quarry A l.f. of the Pawnee Creek Formation (Martin Canyon Beds of earlier workers) in northeastern Colorado (Wilson, 1960).

Erinaceid insectivores and mustelid carnivores of the S/V assemblages each are represented by a few partial teeth that have not been studied in detail.

Lagomorphs, comparatively uncommon in the S/V assemblages, are represented by at least three taxa, including two ochotonids and an archaeolagine. The most common taxon is nearly identical in size and dental morphology to the ochotonid *Cuyamalagus dawsoni* (Hutchison *in* Hutchison and Lindsay, 1974), which is based on an occurrence in the early late Hemingfordian Vedder l.f. of the Branch Canyon Formation in the Sierra Madre Mountains of Santa Barbara County, south-central California. This species also occurs in the Upper Piuma Road l.f. in the Piuma Road area. A larger ochotonid with U-shaped crescents in the upper cheek teeth is referred tentatively to *Gripholagomys* (Green, 1972). Only a few leporid teeth have been recovered and include several P3s clearly referable to *Archaeolagus*. *Archaeolagus* also occurs in the early Arikareean Alamos Canyon l.f. in the transitional zone at the top of the upper member of the Sespe Formation in Simi Valley (Prothero et al., 1996; Lander, 1997). The leporid from the Blakeley l.f. also is assignable to *Archaeolagus*.

Sciurid rodents are represented by at least three taxa in the S/V assemblages, including one or more species each of the chipmunk *Nototamias*, the ground squirrel *Miospermophilus*, and a large species of petauristine. The teeth of *Nototamias* are small with sharp, well-defined lophs on the upper molars. *Nototamias* is a comparatively common element in many of the S/V assemblages. *Nototamias* also is known from the latest Arikareean Upper Harrison Beds in northwestern Nebraska (Korth, 1992) and the early Hemingfordian Thomas Farm l.f. of Florida (Pratt and Morgan, 1989). Teeth referred to *Miospermophilus* display wide morphologic variation, and it is likely that more than one species is present. *Miospermophilus* is known from the Quarry A l.f. of northeastern Colorado (Wilson, 1960) and the early late Hemingfordian Split Rock l.f. in central Wyoming (Black, 1963; Munthe, 1979b). *Miospermophilus* is the most common sciurid in the S/V assemblages. A few very large teeth with highly crenulated enamel are referred questionably to *Petauristodon*. These latter specimens were recovered from strata of early Hemingfordian age at the Santiago Canyon Landfill and in late Arikareean strata in the ETC Santiago Road area. Elsewhere in North America, the first occurrence of *Petauristodon* is in the early Hemingfordian Thomas Farm l.f. (Pratt and Morgan, 1989). *Petauristodon* also is found in the Miocene of Europe.

Eomyid rodents in the S/V assemblages are represented by two species of *Pseudotheridomys*, both species with teeth that bear five well-formed lophs and intervening valleys that are closed by prominent labial and lingual cingula. The smaller species is similar in size and dental morphology to *P. cuyamensis* (Lindsay, 1974) of the Vedder l.f. (Hutchison and Lindsay, 1974; Lindsay, 1974; Munthe, 1979a). This species occurs in only three areas, including ETC Santiago Road (OCPC 2008), ETC Bee Canyon (OCPC 2010), and the Santiago Canyon Landfill. Early Hemingfordian strata at the Santiago Canyon Landfill also have yielded the second eomyid, questionably referred to *Pseudotheridomys*, which has teeth that are 2.5 times larger than those of *P. cuyamensis*.

One locality low in the exposed S/V sequence at the Frank R. Bowerman Landfill yielded small brachydont cheek teeth (LACM 7327) bearing four major cusps and a pronounced cingulum with small stylar cusps in early stages of wear, characteristics all typical of *Heliscomys* (Korth, 1994b).

In terms of numbers of specimens, heteromyid rodents are by far the most common microvertebrates in all of the S/V collecting areas. More than 800 isolated teeth and a few jaws and partial dentitions represent at least four genera, including *Cupidinimus*, *Trogomys*, *Proheteromys*, and *Schizodontomys*. Because of the variable nature of individual dental morphology, species distinctions have not been attempted in the latter three taxa. It is very likely that more than one species of both *Trogomys* and *Proheteromys* could be distinguished following a more detailed analysis.

The bunodont heteromyids in the S/V assemblages are represented by one or more small forms with P4 and p4 that lack accessory cusps, p4 with a central connection between the hypolophid and metalophid, M1–2 and m1–2 with moderate to weak cingula, and molars with crowns having straight anterior and posterior surfaces. This dental morphology is typical of *Perognathus* (Martin, 1984) and the monotypic *Trogomys* from the early Hemingfordian Tick Canyon l.f. (Reeder, 1960). Another group of bunodont heteromyids in the S/V assemblages with similar premolar morphology is represented by teeth that are larger than those referred to *Trogomys*. Cingula on the first and second molars are better developed than in *Trogomys*, and the teeth have a bulbous appearance in occlusal view because of the expanded anterior and posterior surfaces of the crown. This dental morphology has been found in several heteromyines, but it is best developed in *Proheteromys*, a common element in Arikareean and Hemingfordian assemblages (Korth, 1994b).

The mesodont heteromyids in the S/V assemblages are represented by *Cupidinimus* near *C. lindsayi* (Barnosky, 1986) and at least one species of *Schizodontomys*. The *Cupidinimus* teeth are most similar in size and morphology to those of the early Barstovian *C. lindsayi*. The S/V specimens probably represent the oldest record of the genus. Barnosky (1986) recognized the primitive nature of the dental morphology of *C. lindsayi*. The only other Hemingfordian record of the genus is a distinctly larger species, *C. boronensis* of the Boron l.f. (Whistler, 1983), which occurs in the Kramer Beds of the Mojave Desert in Kern County, southern California. *Cupidinimus*, though rare, has been recovered from two areas of Orange County, the ETC Bee Canyon area (OCPC 2008) and the Santiago Canyon Landfill. The other mesodont taxon is large and, as in *Schizodontomys* and a number of other geomyoids, has much higher-crowned, lophodont teeth with reduced cusps. This taxon is common in late Arikareean and early Hemingfordian assemblages of the ''Sespe'' lithofacies but is lacking in assemblages of the ''Vaqueros'' lithofacies. *Schizodontomys* is known primarily from early Hemingfordian assemblages (Korth, 1994b). R.H. Tedford and X. Wang (personal commun.) recognize a single specimen referable to *Cephalogale* from locality OCPC 2040.

The eucricetodontine rodents are among the more important age-diagnostic taxa in the S/V assemblages. Three species are present, two of which are probably undescribed new species. One of the species is second only to the heteromyids in the total number of specimens recovered, but the other two taxa are comparatively uncommon. The common species is the largest of the three, with molars that develop enamel-lined lakes in moderate wear stages. The anterior enamel surface of the lower incisor has a distinctive pattern of one or two weak lingual ridges and three more distinct labial ridges. This enamel ridge pattern is typical of *Leidymys* (Engesser, 1979; Martin, 1980) and is most similar to the pattern of the early Arikareean species *Leidymys nematodon* (Cope, 1879) from the John Day Formation of central Oregon. *L. nematodon* is restricted to the Arikareean portion of the S/V. Lander (1994a, 1997) and Lander et al. (2001) assigned an upper incisor of a cricetid from the Alamos Canyon l.f. to *L. nematodon*. The Blakeley *Leidymys* is probably referable to *L. nematodon* as well. A smaller species of *Leidymys* in the S/V assemblages, herein referred to as *Leidymys* sp. (small), is about 20% smaller than *L. nematodon*. The three labial ridges on the lower incisor of this smaller species of *Leidymys* are situated more centrally than in *L. parvus* or *L. nematodon*. In the S/V, *Leidymys* sp. (small) is restricted to assemblages of latest Arikareean and early Hemingfordian age.

A third eucricetodontine species in the S/V assemblages is referred to the monotypic *Yatkolamys*. This species is similar to *Copemys* in terms of cheek tooth morphology, with molars that do not develop enamel lakes and with smaller M1 anterocones and m1 anteroconids than in *Leidymys*. The lower incisor has only two weak ridges near the labial margin and a series of fine ridges across the remainder of the anterior surface of the tooth. This pattern of enamel ridges is most similar to that of *Yatkolamys edwardsi* (Martin and Corner, 1980) from the lower part of the early Hemingfordian Runningwater Formation in northwestern Nebraska and the Hemingfordian Cypress Hills Formation of Saskatchewan (Skwara, 1988). *Yatkolamys*, though rare, is found in four early Hemingfordian S/V assemblages and in the Upper Piuma Road l.f. of the Piuma Road area (Lander et al., 2001). These records of the genus are designated *Yatkolamys* sp.

The larger vertebrate taxa, including carnivores, artiodactyls, and perissodactyls, of the S/V assemblages are represented by far fewer specimens than the microvertebrates. H. M. Wagner (SDNHM) examined the amphicyonids and canids from the S/V assemblages of the ETC and FTC/Oso areas and the Frank R. Bowerman and Santiago Canyon Landfills. The following discussion is based on his analysis. A palate of a large amphicyonid specimen (OCPC 21791) is most similar in size and dental morphology to *Cynelos helbingi* (Dehm, 1950) from the Burdigalian (late early Miocene) Wintershof West fauna of Germany (see Hunt, 1972, 1998). Several comparatively large canid specimens (LACM 148403, OCPC 21794) appear to represent a new genus and species of borophagine canid that, despite differences in size and the morphology of the p1–3, the P1–3, and, in particular, the P4, is nearest to either *Phlaocyon* or *Protomarctus* (see Wang et al., 1999). There also is a small canid represented by a palate and a P4 (LC 9112, 9114a) that might be referable to *Phlaocyon achoros* (Frailey, 1979), which is based on an occurrence in the post-Arikareean, pre-Hemingfordian Buda l.f. of Florida. Lander and Whistler (appendix: 1999) questionably referred LC 9114a to *Broiliana*. Another small canid (OCPC 21796) resembles the borophagine *Cynarctoides gawnae* (Wang et al., 1999) in dental morphology and dimensions of the lower premolars and m1. Lander (appendix: 1994b) referred a specimen (LC 7692) from the Santiago Canyon Landfill to the borophagine *Tomarctus canavus* (Simpson, 1932), which is based on an occurrence in the early Hemingfordian Thomas Farm l.f. of Florida. There also are two specimens of a small member of the Caninae (LACM 14840, LC 9114b) that resembles *Metalopex*. Based on the material available, the latter two specimens probably cannot be distinguished from what is generally referred to as ''*Leptocyon*'' and, therefore, this more conservative taxonomic approach is used in tables 11.1 and 11.2 and figure 11.4. R. H. Tedford and X. Wang (personal commun.) recognize a single specimen referable to *Cephalogale* from locality OCPC2040.

A palate referred to *Daeodon hollandi* (Peterson, 1905) was recovered at the Bolero Lookout locality (Lucas et al., 1997). A small quadrate M1 (LACM 144102) bearing four low, rounded cusps from the Parkridge area appears to represent the small peccary ''*Cynorca*'' *sociale* (Marsh, 1875; quotes follow Wright, 1998).

Based on size and dental morphology, two oreodontids are present in the S/V assemblages. Several localities near the base of the exposed S/V sequence at the Frank R. Bowerman Landfill yielded skulls and dentaries (LACM 145833, 145850–52, 148405, 148415, 148416) of the only species of the small hypsodont, early Arikareean oreodontid *Sespia nitida* (includes *S. californica* Stock, 1930; Lander, 1997, 1998). One additional specimen (OCPC 22096) was recovered at a stratigraphic level low in the S/V of the ETC at OCPC 2075 (locality not shown in fig. 11.3 because the site is an isolated occurrence between Jamboree Road and Windy Ridge). These specimens are similar to other specimens of *S. nitida* and unlike specimens of *Leptauchenia* (as revised by Lander, 1998) in terms of their comparatively small size and more hypsodont dentition.

A number of crushed partial skulls (LC 7571, 7696, 7802, 7836, 7847) of a larger mesodont oreodontid in the S/V assemblages were recovered at the Santiago Canyon Landfill. These specimens are assigned to *Merychyus arenarum* (Cope, 1884) on the basis of their cranial and dental morphologies and size (Lander, 1997, 1998). The lacrimal fossa in these specimens is a broad, shallow, flat-bottomed depression as in *Merychyus* and *Paroreodon*. The auditory tube is a highly inflated saclike structure completely filling the space between the postglenoid and paroccipital processes. Though crushed, the tympanic bulla appears to have had a flattened or slightly convex ventral surface that sloped steeply anteromedially. A crushed skull (OCPC 22097) of *Merychyus* from the ETC Windy Ridge area at OCPC 2062 represents an individual similar in size to those from the Santiago Canyon Landfill. The anterior intermediate crest of the P1–3 in these specimens is oriented anteromedially rather than forming an isolated cusp at the anteromedial corner of the tooth. This premolar morphology is like that found in *M. crabilli* and *M. elegans* but unlike that of *M. relictus* from the latest Hemingfordian and early Barstovian. The landfill sample and OCPC 22097 represent individuals similar in size to *M. elegans* from the early Hemingfordian Runningwater Formation (Marsland and restricted Runningwater formations of earlier workers) in northwestern Nebraska and eastern Wyoming.

Based on size and dental morphology, two camelids are present in the S/V assemblages of the Santiago Canyon Landfill and ETC Windy Ridge area. Both taxa have constricted rostra and double-rooted P1s and p1s and, therefore, are assignable to the Protolabinae (Honey et al., 1998). In terms of its comparatively small incisiform I1–3 and C, the smaller protolabine (LC 7809) is similar to *Michenia agatensis* (Frick and Taylor, 1971) from the latest Arikareean Upper Harrison Beds of northwestern Nebraska. Based on its

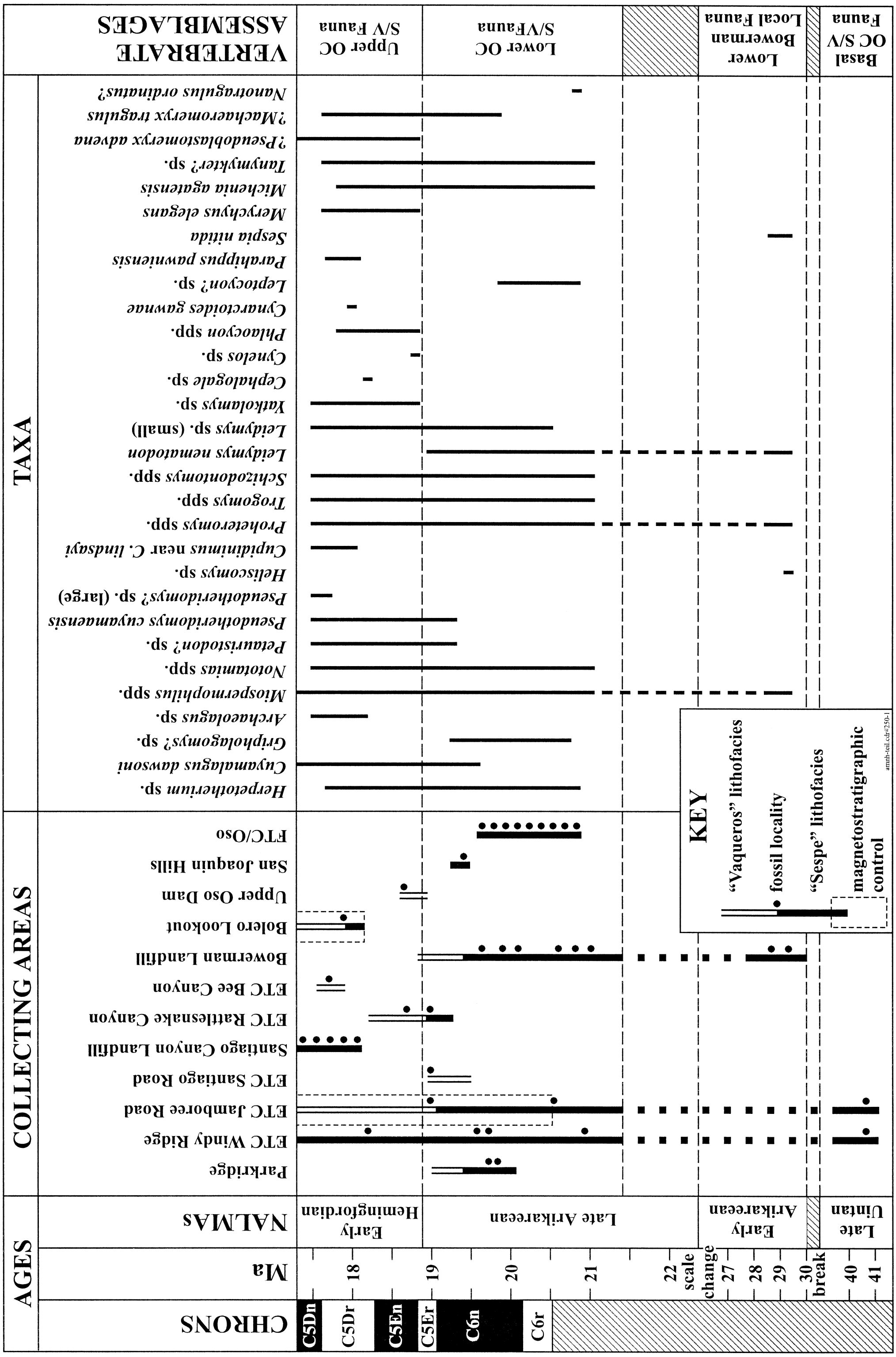

Fig. 11.4. Teilzones of age-diagnostic taxa, temporal ranges of continental vertebrate assemblages, stratigraphic ranges of collecting areas, and stratigraphic levels of fossil localities in Sespe Formation and S/V in fossil collecting areas, Santa Ana Mountains and San Joaquin Hills, southern Orange County, California. Ranges of taxa constituting late Uintan Basal Orange County S/V fauna not included.

comparatively large caniniform I1–3 and C, the larger protolabine (LC 7798) is similar to *Tanymykter brachyodontus* (Peterson, 1904) from the early Hemingfordian Runningwater Formation (Upper Loup Fork Beds of earlier workers) of northwestern Nebraska (see Honey and Taylor, 1978). However, other early Hemingfordian protolabines, including *Protolabis*, are similar in terms of size and cranial and dental morphologies to *Tanymykter*. Therefore, the larger protolabine is referred only tentatively to *Tanymykter*. The two S/V taxa can be distinguished on the basis of size: the P2–M3 and p2–m3 lengths of the S/V examples of *T. brachyodontus* average approximately 25 percent larger than those of *M. agatensis*.

A partial maxillary (OCPC 22099) and two partial dentaries (OCPC 22037, 22094) of a small blastomerycine in the S/V assemblages of the ETC Windy Ridge area and a partial skull and mandible (LC 8589) of a small blastomerycine from the Santiago Canyon Landfill probably represent *Machaeromeryx tragulus* (Matthew, 1926), which is based on a specimen from the latest Arikareean Upper Harrison Beds of northwestern Nebraska. A partial skull and mandible (OCPC 21790) of a larger blastomerycine from the S/V assemblages in the ETC Windy Ridge area probably represent *Pseudoblastomeryx advena* (Matthew, 1907), which is based on a specimen from the earliest Hemingfordian Upper Rosebud Beds of southwestern South Dakota. Several lower molars of a larger blastomerycine from the Santiago Canyon Landfill probably also represent *P. advena*. The two S/V blastomerycines can be distinguished on the basis of size: the P2–M3 and p2–m3 lengths of the S/V examples of *P. advena* average approximately 25 percent larger than those of *M. tragulus*.

A hypertragulid from the lower part of the exposed section of the Sespe Formation in the FTC/Oso area at LC 202 is assigned to *Nanotragulus*. This occurrence is the only record of a hypertragulid from the S/V and the Sespe Formation in Orange County. An m3 (LC 9237) from LC 202 is more hypsodont than in any early Arikareean specimen of *Nanotragulus* and *Allomeryx* from early Arikareean strata in the central Great Plains, California, Oregon, and Washington, or any example of *Hypertragulus*, including *H. calcaratus* (Cope, 1873) from Orellan strata in the central Great Plains, and is much smaller than in *Allomeryx* (see Lander, 1983; Lander and Swanson, 1989; Sinclair, 1905). Possibly, the Orange County species is assignable to *Nanotragulus ordinatus* (Matthew, 1907), which is based on a specimen of presumed late Arikareean age from the Lower Rosebud Beds of southwestern South Dakota.

According to Lander (1983), *H. calcaratus* includes *H. fontanus* (Stock, 1935) from the Orellan or Whitneyan Kew Quarry l.f. in the upper member of the Sespe Formation at LACM(CIT) 126 in the Las Posas Hills of Ventura County (Lander, 1983, 1994a, 1997; Prothero et al., 1996). *H. fontanus*, which is based on a skull, was assigned incorrectly to *Nanotragulus* by Tedford et al. (1987) and Webb (1998). However, as in *H. calcaratus* and unlike early Arikareean *Nanotragulus loomisi* (Lull, 1922) from the central Great Plains and the John Day Formation of central Oregon, the tympanic bulla of the type specimen of *H. fontanus* is comparatively uninflated and the periotic still protrudes between the tympanic bulla and the basioccipital.

Probably assignable to *Nanotragulus*, however, is the early Arikareean hypertragulid from the upper member of the Sespe Formation (Alamos Canyon, Blakeley l.f.s) in Simi Valley and the upper part of the undifferentiated Sespe Formation at South Mountain (South Mountain l.f.) in Ventura County, the latter specimens previously having been assigned to *Hypertragulus hesperius* (Hay, 1902) by Webb (1998) and questionably by Lander (1983), and to *Nanotragulus* (= *Hypertragulus*) *fontanus* by Tedford et al. (1987) and Webb (1998). Possibly, these specimens are assignable to *N. loomisi*.

Carroll (1988) and McKenna and Bell (1997) assigned *Allomeryx* to *Hypertragulus*. Although *Allomeryx* is much larger than *Hypertragulus* and, unlike *Hypertragulus*, the type specimen has a complete postorbital bar (bar incomplete in all topotypic specimens), the two taxa are similar enough for *Allomeryx* to have been derived from *Hypertragulus*. *Allomeryx* was assigned incorrectly to *Nanotragulus* by Webb (1998), even though

Allomeryx is very similar to *Hypertragulus* and is less derived and unlike contemporary examples of *Nanotragulus* in the morphologies of the tympanic bulla and periotic. Although the morphology of the third lower molar of *Allomeryx* is similar to that of *Nanotragulus* from the early Arikareean, in *Nanotragulus* the tympanic bulla is comparatively inflated and contacts the basioccipital, the periotic no longer protruding between tympanic bulla and basioccipital. Presumably, *Hypertragulus* gave rise to both *Allomeryx* (= *Hypertragulus*) and *Nanotragulus* near the Whitneyan/Arikareean boundary.

A dentary (LC 7693) and an M1 (LC 7845) of a small rhinocerotid were recovered at the Santiago Canyon Landfill. These specimens are most similar to earliest Hemingfordian *Menoceras falkenbachi* (Tanner, 1972) from the lower part (Marsland Formation of earlier workers) of the Runningwater Formation in northwestern Nebraska in terms of size and the simple occlusal morphology of the M1. Prothero (1998) and Prothero et al. (1989) assigned *M. falkenbachi* to *Menoceras barbouri* (Wood, 1964), which is based on an occurrence in the early Hemingfordian Thomas Farm l.f.

Based on size and dental morphology, two equid species are present in the S/V assemblages. A partial skull (LC 8945) of a comparatively small equid was recovered at the Santiago Canyon Landfill. As in *Parahippus*, a well-developed crochet projects anteriorly from the middle of the metaloph toward the protoconule of the P2–M3. The dentition is comparatively brachydont and similar in size to that of *Parahippus pawniensis* (Gidley, 1907) from the Martin Canyon l.f. of the Pawnee Creek Formation in northeastern Colorado. The Bolero Lookout locality yielded an equid M3 that also is assignable to *P. pawniensis* (Lucas et al., 1997). Contrary to the findings of earlier workers (Savage, 1972; Raschke, 1984a), *Miohippus* is not recorded from the Sespe Formation in Orange County. Based on their comparatively large size and brachydont dentitions, two dentary fragments with cheek teeth from the Santiago Canyon Landfill are assigned questionably to *Kalobatippus clarencei* (Simpson, 1932), which is based on an occurrence at Thomas Farm.

ORANGE COUNTY S/V BIOSTRATIGRAPHY

The teilzones of age-diagnostic taxa in the Sespe Formation and the S/V of Orange County are shown in figure 11.4. As stated above, a composite biostratigraphic framework has been developed for these geologic units based on the integration of overlapping teilzones documented in numerous isolated fossil-bearing stratigraphic successions. These successions lack laterally continuous marker beds that would have allowed the direct physical correlation of fossil-bearing strata between adjacent successions. Many of these successions contain superposed fossil assemblages (or local faunas; fig. 11.3), some successions exhibiting marked faunal changes between successive fossil localities. However, stratigraphic separation between successive fossil localities in a single succession does not necessarily correlate with the degree of faunal change, possibly because the S/V represents a number of marine transgressive/regressive events and, therefore, may include unconformities. Many of the superposed fossil assemblages are restricted to a single fossil collecting site, and most of these subsequently have been destroyed, thus we are hesitant to introduce too many new local faunal names where little or no opportunity will exist to duplicate the collecting effort. However, for the purposes of this report, the following local faunas are defined using the names listed under ‘‘Collecting Areas’’ in figures 11.3 and 11.4. The faunal compositions of the local faunas and specific collecting sites are presented in tables 11.1 and 11.2. A more detailed discussion of the lithology and stratigraphic context of each collecting area has been presented above.

PARKRIDGE L.F.: Localities LACM 6927–6930 in ‘‘Sespe’’ lithofacies. These localities produced only larger vertebrate specimens.

LOWER ETC WINDY RIDGE L.F.: Localities OCPC 2016–2018 in ‘‘Sespe’’ lithofacies in 290 m of section below locality OCPC 2019. Locality OCPC 2017 produced only microvertebrate specimens.

UPPER ETC WINDY RIDGE L.F.: Microvertebrate locality OCPC 2019 and larger vertebrate locality OCPC 2040 in ‘‘Sespe’’ lithofacies in 140-m section below contact with overlying Topanga Formation.

ETC JAMBOREE ROAD L.F.: Microvertebrate locality OCPC 2014 in ''Sespe'' lithofacies 650 m below transitional zone with ''Vaqueros '' lithofacies (apparent thickness of section might be result of repetition caused by unrecognized faulting), and microvertebrate locality OCPC 2013 in ''Vaqueros'' lithofacies 20 m above transitional zone with ''Sespe'' lithofacies.

ETC SANTIAGO ROAD L.F.: Microvertebrate locality OCPC 2008 in fault-bounded block in ''Vaqueros'' lithofacies, although assemblage lacks marine vertebrates. Most productive microvertebrate locality, with 603 catalogued specimens.

SANTIAGO CANYON LANDFILL L.F.: Localities LC 151, LC 152, and LC 162 through LC 174 in ''Vaqueros'' lithofacies. Most localities yielded both microvertebrate and larger vertebrate specimens.

LOWER ETC RATTLESNAKE CANYON L.F.: Microvertebrate locality OCPC 2012 in 100-m section of ''Sespe'' lithofacies.

UPPER ETC RATTLESNAKE CANYON L.F.: Microvertebrate locality OCPC 2027 in ''Vaqueros'' lithofacies.

ETC BEE CANYON L.F.: Microvertebrate locality OCPC 2010 in 50-m section typical of redbed ''Sespe'' lithofacies, but abundant marine vertebrates (sharks, rays, teleosts) suggest marine origin.

LOWER BOWERMAN LANDFILL L.F.: Localities LACM 6941 and LACM 7326–7328 in 30-m section of ''Sespe'' lithofacies in two different areas of Frank R. Bowerman Landfill excavations as they existed in 1996.

UPPER BOWERMAN LANDFILL L.F.: Localities LACM 6935–6940 and LACM 6942–6945 in 170-m section of ''Sespe'' lithofacies overlain by unmeasured section of ''Vaqueros'' lithofacies. Many localities yielded both microvertebrate and larger fossil vertebrate specimens.

BOLERO LOOKOUT L.F.: Locality LACM (CIT) 449 in transitional zone between ''Sespe'' lithofacies and 20-m section of overlying ''Vaqueros'' lithofacies (Belyea and Minch, 1989; Lucas et al., 1997). This locality yielded only larger fossil specimens.

UPPER OSO DAM L.F.: Localities LACM 4554, 4555, 4559, and 4560 in upper 34-m section of ''Vaqueros'' lithofacies underlying Topanga Formation (Rashcke, 1984a, 1984b). Localities also yielded marine vertebrate specimens.

SAN JOAQUIN HILLS L.F. (as defined by Conkling et al., 1997 [appendix]): Locality LSA SR-73 and others in ''Sespe'' lithofacies.

FTC/OSO L.F.: Microvertebrate localities LC 196–205, in 170-m section of ''Sespe'' lithofacies. Localities LC 199, 202, and 205 also yielded larger vertebrates.

Faunal changes between stratigraphically superposed localities in the thicker stratigraphic successions first were documented to allow the development of the composite biostratigraphic framework presented in figure 11.4. Patterns that emerged in these successions were integrated into a framework that included all of the collecting areas.

Based on data presented in table 11.1 and figures 11.3 and 11.4, we recognize four stratigraphically superposed faunas in the S/V of southern Orange County. The comparatively taxonomically diverse late Uintan Basal Orange County S/V fauna (new name) occurs near the base of the S/V. The relatively limited early Arikareean Lower Bowerman l.f. (new name) lies stratigraphically above the Basal Orange County S/V fauna. The stratigraphically superposed late Arikareean Lower Orange County S/V fauna (new name) and overlying late Arikareean to early

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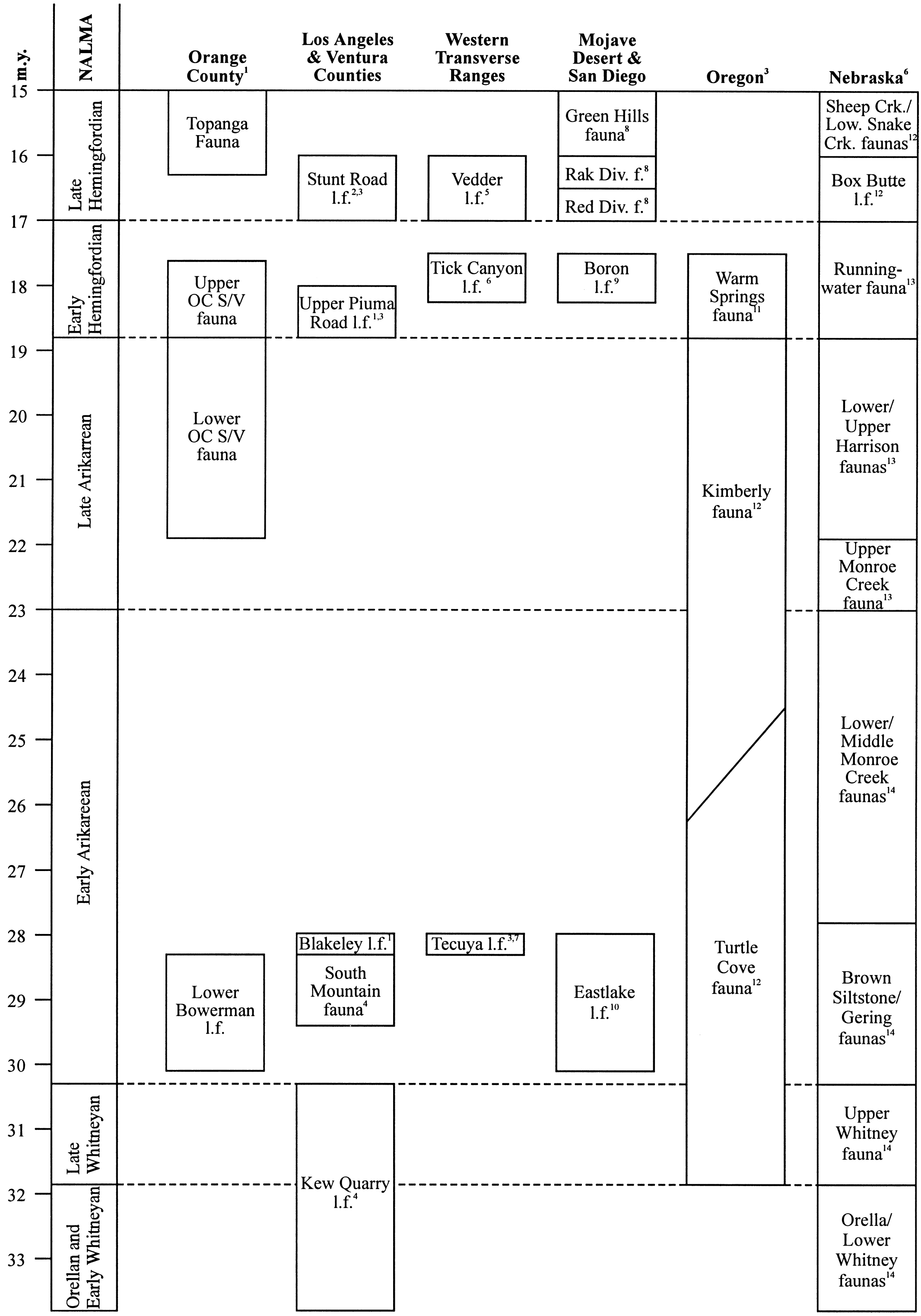
Fig. 11.5. Correlation chart showing ages and temporal relationships of continental vertebrate assemblages from southern Orange County, California, and other fossiliferous areas in California, Oregon, and Nebraska. Late Uintan Basal Orange County undifferentiated Sespe/Vaqueros fauna not included. *Sources:* 1) this paper, Donohoo and Prothero (1999), Lander (1994a), Lucas et al. (1997); 2) this paper, Kelly and Lander (1988); 3) Lander et al. (2001); 4) Lander (1983, 1994a, 1997), Prothero et al. (1988), Walsh and Deméré (1991); 11) Dingus (1978, 1990); 12) Tedford et al. (1987); 13) MacFadden and Hunt (1998); 14) Tedford et al. (1985, 1996).


m.y.
NALMA
Orange County[1]
Los Angeles & Ventura Counties
Western Transverse Ranges
Mojave Desert & San Diego
Oregon[3]
Nebraska[6]
15
16
17
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Late Hemingfordian
Early Hemingfordian
Late Arikarrean
Early Arikareean
Late Whitneyan
Orellan and Early Whitneyan
Topanga Fauna
Upper OC S/V fauna
Lower OC S/V fauna
Lower Bowerman l.f.
Stunt Road l.f.[2,3]
Upper Piuma Road l.f.[1,3]
Blakeley l.f.[1]
South Mountain fauna[4]
Kew Quarry l.f.[4]
Vedder l.f.[5]
Tick Canyon l.f.[6]
Tecuya l.f.[3,7]
Green Hills fauna[8]
Rak Div. f.[8]
Red Div. f.[8]
Boron l.f.[9]
Eastlake l.f.[10]
Warm Springs fauna[11]
Kimberly fauna[12]
Turtle Cove fauna[12]
Sheep Crk./ Low. Snake Crk. faunas[12]
Box Butte l.f.[12]
Running-water fauna[13]
Lower/ Upper Harrison faunas[13]
Upper Monroe Creek fauna[13]
Lower/ Middle Monroe Creek faunas[14]
Brown Siltstone/ Gering faunas[14]
Upper Whitney fauna[14]
Orella/ Lower Whitney faunas[14]

Hemingfordian Upper Orange County S/V fauna (new name) occur in the upper 200 m of the S/V. These two taxonomically diverse faunas represent numerous assemblages.

Included in figure 11.3 (but not fig. 11.4 or tables) are late Uintan continental vertebrate assemblages occurring near the base of the S/V in the Jamboree Road collecting area (localities OCPC 2021, 2024) and in the badlands northwest of the ETC Windy Ridge area (locality OCPC 2020). These assemblages, the Basal Orange County S/V fauna, contain typical late Uintan taxa, including melanosaurine and glyptosaurine lizards, *Palaeoxantusia*, *Parasauromalus*, a boid snake, *Peradectes californicus* (Stock, 1936), *Sespedectes singularis* (Stock, 1935), *Dyseolemur pacificus* (Stock, 1934), small creodonts, *Microparamys woodi* (Kelly and Whistler, 1994), *Pareumys*, *Griphomys alecer* (Wilson, 1940), *Simimys simplex* (Wilson, 1935), and *Leptoreodon*. These assemblages are comparable to the Tapo Canyon and Brea Canyon l.f.s from the middle member of the Sespe Formation in Simi Valley (Golz and Lillegraven, 1977; Kelly, 1990; Kelly et al., 1991; Kelly and Whistler, 1994; Lander, 1997).

As shown in figure 11.3, the Lower Bowerman l.f. is derived from four localities (LACM 6941, 7326, 7327, 7328) at the Frank R. Bowerman Landfill. Table 11.2 includes a listing of taxa from these localities. The Lower Bowerman l.f. is characterized by the restricted local stratigraphic occurrences of the rodent *Heliscomys* and the oreodontid *Sespia*. The l.f. also contains a small sciurid possibly assignable to *Miospermophilus* and the rodents *Proheteromys* and *Leidymys nematodon*. *Sespia* also occurs at a stratigraphic level low in the S/V of the ETC at OCPC 2075.

The Lower Orange County S/V fauna is a composite of the Parkridge, Lower ETC Windy Ridge, ETC Jamboree Road, ETC Santiago Road, Lower ETC Rattlesnake Canyon, Upper Bowerman Landfill, San Joaquin Hills, and the FTC/Oso l.f.s. The fauna is characterized by the restricted local stratigraphic occurrences of the ochotonid *Gripholagomys*, the canid *Leptocyon*?, and a comparatively hypsodont species of the hypertragulid *Nanotragulus*, *N. ordinatus*?. The fauna also is characterized by the first local occurrences, stratigraphically low in the fossil-bearing interval containing the fauna, of the didelphid *Herpetotherium*; the rodents *Nototamias*, *Trogomys*, and *Schizodontomys*; the camelids *Michenia agatensis* and ?*Tanymykter brachyodontus*; and, higher in the interval, the ochotonid *Cuyamalagus dawsoni*; the leporid *Archaeolagus*; the rodents *Petauristodon*?, *Pseudotheridomys cuyamensis*, and a small, undescribed species of the cricetid *Leidymys*; and the blastomerycine ?*Machaeromeryx tragulus*. The larger *Leidymys nematodon* occurs throughout most of the fossil-bearing interval, last appearing just below the top of the interval.

The Upper Orange County S/V fauna is a composite of the Upper ETC Windy Ridge, Santiago Canyon Landfill, Upper ETC Rattlesnake Canyon, ETC Bee Canyon, Bolero Lookout, and the Upper Oso Dam l.f. The fauna is characterized by the first or restricted local stratigraphic occurrences of a number of rodent taxa (including a large eomyid questionably referred to *Pseudotheridomys*, the heteromyid *Cupidinimus* near *C. lindsayi*, and the cricetid *Yatkolamys*), the amphicyonid *Cynelos*, the canids *Cephalogale*, *Cynarctoides gawnae* and *Phlaocyon*, the rhinocerotid *Menoceras barbouri*, the equid *Parahippus pawniensis*, the oreodontid *Merychyus elegans*, and the blastomerycine ?*Pseudoblastomeryx advena*.

AGES AND CORRELATION OF ASSEMBLAGES

Figure 11.5 shows the ages of the faunas in the S/V relative to other faunas of similar age elsewhere in southern California and Oregon and the type sections for the Arikareean and Hemingfordian NALMAs in Nebraska. Although a local biostratigraphic framework has been developed for the S/V, correlation with faunas in Oregon and Nebraska is difficult because of the apparent endemism displayed by the southern California assemblages. Common taxa found elsewhere but absent in Orange, Los Angeles, and Ventura counties include castorids, aplodontids, mylagaulids, pleurolicines, florentiamyids, zapodids, the *Gregormys*/*Grangerimus* complex, *Leptauchenia*, and advanced *Merycochoerus*. The absence of these and other taxa probably is a result of regional endemism, which might be a reflection of the coastal distribution of the S/V assemblages. The late Arikareean Lower Orange County S/V fauna appears to represent an assemblage that has not been recognized previously in the S/V and a time interval that is poorly represented in the fossil land mammal record of southern California.

The time span represented by the S/V now can be documented on the basis of integrated biostratigraphic, biochronologic, and magnetostratigraphic data. The Basal Orange County S/V fauna, the oldest assemblage from the lowermost part of the S/V, is a correlative of the late Uintan Tapo Canyon and Brea Canyon l.f.s, which occur in Chron C18r and could be as old as 41.3 Ma (see Berggren et al., 1995; Prothero et al., 1996; Lander, 1997). The youngest assemblages are from the uppermost part of the S/V and contain a number of early Hemingfordian taxa, including the rodents *Cupidinimus* near *C. lindsayi* and *Yatkolamys*, the equid *Parahippus pawniensis*, and the oreodontid *Merychyus elegans*.

On the basis of magnetostratigraphic data recovered from the ETC south of Jamboree Road and at Bolero Lookout, Donohoo and Prothero (1999) considered the uppermost part of the S/V to be assignable to Chrons C5Er to C5Cr and approximately 19.1 to 16.7 Ma (see Berggren et al., 1995). This assignment was influenced, in part, by preliminary age estimates of the associated fossil assemblages provided by the authors of the current paper. However, based on more recent biostratigraphic comparisons, the present study indicates that the assemblage that occurs in the ETC Jamboree Road collecting area at localities OCPC 2014 and 2013 is late Arikareean rather than early Hemingfordian in age. To ensure that magnetostratigraphic data provided by Donohoo and Prothero (1999) were consistent with the biostratigraphic data used to construct the biostratigraphic framework presented in figure 11.4, this change required reassigning the lower locality (OCPC 2014) from Chron C5Er to Chron C6r (20.5 to 20.1 Ma) and the upper locality (OCPC 2013) from Chron C5Dr to Chron C5Er (19.1 to 18.8 Ma). Pending further investigation, the assignment by Donohoo and Prothero (1999) of the Bolero Lookout site to Chron C5Dr (18.3 to 17.6 Ma) is considered reliable.

Despite the high degree of faunal endemism, some geographically wide-ranging but temporally restricted taxa occurring in some of the S/V assemblages permit long-range correlations. *Sespia* is restricted to assemblages of early Arikareean age in the northern Great Plains area of Colorado, Nebraska, South Dakota, and Wyoming; the northern Rocky Mountain area of Montana; and the western Transverse Ranges of Ventura and Santa Barbara counties in coastal southern California (Lander, 1983, 1994a, 1997; Tedford et al., 1985, 1987, 1996). In California, *Sespia* has been recovered from localities in the upper member of the Sespe Formation and in laterally equivalent continental and marine strata in Ventura and Santa Barbara counties, and in the Otay Formation (Eastlake l.f.) of San Diego County (Lander, 1983, 1994a, 1997; Deméré, 1988; Walsh and Deméré, 1991). The Sespe Formation records occur above the last local occurrence of *Palaeolagus* in the Kew Quarry l.f. but below the first local occurrences of *Archaeolagus* and *Leidymys nematodon* in the Alamos Canyon and Blakeley l.f.s (Lander, 1983, 1994a, 1997). The marine occurrence (Cañada de la Gaviota l.f.) of *Sespia* was recovered from Member B of the Alegria Formation (Lander, 1983, 1994a, 1997), within the stratigraphic range of a pelecypod transitional between *Vertipecten yneziana* and *V. perrini* and assignable to an unnamed late Eocene to early Oligocene provincial marine molluscan stage (see Addicott, 1972; Smith, 1991). The age of the Eastlake l.f. is constrained by a K/Ar radiometric date of 28.86 Ma (Berry, 1991; Walsh and Deméré, 1991). This date is consistent with an Ar/Ar date of 28.2 $\pm$ 0.2 Ma for the Willard Canyon Tuff of the Sepe Formation at South Mountain in Ventura County (Mason and Swisher, 1989; Prothero et al., 1996).

In the central Great Plains, the first appearance of *Sespia* is very near the beginning of the Arikareean NALMA (Tedford et al., 1985, 1987, 1996). In the Brown Siltstone Beds of the Brule Formation in Nebraska, the first occurrence of *Sespia* is less than 5 m below the Nonpareil Ash Zone (NP_3), which has been radiometrically dated at 30.05 Ma (see also Berggren et al., 1995). The last local occurrence is in the overlying Monroe Creek Formation (Middle Monroe Creek Beds of earlier workers). *Heliscomys* is common in faunas of Oligocene (including early Arikareean) age (Korth, 1994b). *Heliscomys* and *Sespia* are restricted to the Lower Bowerman l.f. and the S/V assemblage in the ETC at OCPC 2075 and indicate that these are early Arikareean in age.

The most age-diagnostic rodent of the Lower Orange County S/V fauna is *Leidymys nematodon*, which is restricted to assemblages of Arikareean age (Korth, 1994a). *Herpetotherium*, *Miospermophilus*, *Nototamias*, *Proheteromys*, and *Schizodontomys* all are typical of, but not restricted to, assemblages of late Arikareean age (Korth, 1994b). Petauristine rodents, which are represented by *Petauristodon*? in the Lower Orange County S/V fauna, are a common European group that first appears in North America in the early Hemingfordian (Engesser, 1979; Korth, 1994b). The occurrence of a comparatively hypsodont species of *Nanotragulus*, *N. ordinatus*?, suggests that the fauna is late Arikareean in age. The last occurrence of *Nanotragulus* is in assemblages of late Arikareean age (Tedford et al., 1987).

The Upper Orange County S/V fauna contains the first local occurrences of taxa that elsewhere are restricted to assemblages of Hemingfordian and younger age. Two rodents in this fauna, *Cupidinimus* and *Yatkolamys*, are particularly age diagnostic. The undescribed species of *Cupidinimus* is most similar to early Barstovian *C. lindsayi* (Barnosky, 1986). The S/V occurrence is the oldest record of the genus, and the dental morphology is similar to that which Barnosky (1986) predicted would be observed in the ancestor of *C. lindsayi*. Previously, the oldest record of *Cupidinimus* was the slightly younger species *C. boronensis* (Whistler, 1984) of the Boron l.f. of the Mojave Desert in southern California. The occurrence of this new species in the S/V supports the suggestion by Barnosky (1986) that the genus originated in the southwestern United States.

Yatkolamys is the last record of the taxonomically highly diverse eucricetodontines of the Oligocene and early Miocene. Previous records of *Yatkolamys* were restricted to the early Hemingfordian assemblages of Nebraska and Saskatchewan (Martin and Corner, 1980; Skwara, 1988). Recently, another record of the genus was recovered from the top of the Piuma Member of the Sespe Formation, representing one of the first age-diagnostic land mammal occurrences from the formation in the Santa Monica Mountains. Dingus (1978) also recognized the presence of a small cricetid in the early Hemingfordian Warm Springs l.f., which occurs in the uppermost part of the John Day Formation in Oregon. Dingus (1978) tentatively referred the cricetid to the Eurasian genus *Eumyarion*. This record may represent another species of *Yatkolamys*. Although they have ranges that extend downward into the uppermost part of the underlying Lower Orange County S/V fauna, two other taxa, the ochotonid *Cuyamalagus dawsoni* and the rodent *Pseudotheridomys cuyamensis*, are based on occurrences in the early late Hemingfordian Vedder l.f. of south-central California.

Previously, the borophagine canid *Cynarctoides gawnae* was reported only from the upper part of the Chamisa Mesa Member of the Zia Sand in New Mexico (Wang et al., 1999). The presence of the amphicyonid *Cynelos* represents one of the earlest records of the genus in North America and one only slightly younger than the late Arikareean occurrence in the Agate Bonebed at the base of the Upper Harrison Beds in northwestern Nebraska (see Hunt, 1998). The equid *Parahippus pawniensis*, the rhinocerotid *Menoceras barbouri*, the oreodontid *Merychyus elegans*, and the blastomerycine *Pseudoblastomeryx advena* also occur in a number of assemblages of early Hemingfordian age, including the Warm Springs l.f. of central Oregon and the Martin Canyon l.f. of northeastern Colorado, and in strata of early Hemingfordian age in the Chamisa Mesa Member and in the Runningwater Formation (Upper Loup Fork Beds and Marsland Formation of earlier workers) of northwestern Nebraska (Dingus, 1990; Lander, 1998; MacFadden, 1998; Prothero, 1998; Webb, 1998). Occurrences of these taxa in strata or assemblages of late Arikareean or late Hemingfordian age are comparatively rare.

CONCLUSIONS

Study of the fossil land mammal assemblages of the undifferentiated Sespe and Vaqueros formations in Orange County, California (S/V), has led to the recognition of a succession of continental vertebrate assemblages (local faunas and faunas) of late Uintan, early and late Arikareean, and early Hemingfordian age. These assemblages contain abundant microvertebrate taxa and significant larger vertebrate taxa. The late Uintan assemblages are the first vertebrate records of this age in Orange County. Three taxonomically distinct faunal assemblages are recognized in the upper (Arikareean and early Hemingfordian) part of the S/V. These latter assemblages demonstrate a comparatively high degree of regional endemism, particularly with regard to the rodents. Faunal endemism has made it difficult to correlate these assemblages with assemblages of similar age in central Oregon (John Day Formation) and in the type areas for the Arikareean and Hemingfordian NALMAs in the central Great Plains of the United States.

Study of these assemblages in conjunction with geologic data (stratigraphic, magnetostratigraphic) has been critical in reconstructing the marine and nonmarine depositional paleoenvironments represented by the fossil-bearing strata (see Schoellhamer et al., 1981; Belyea and Minch, 1989; Howard; 1989; Minch et al., 1989; Daniel-Lyle, 1995) and in confirming the late Uintan (late middle Eocene) to early Hemingfordian (late early Miocene) age assignments for the fossil-bearing interval. These data indicate that the S/V is 41.3 to 17.6 Ma and that it might contain one or more depositional hiatuses. The base of the S/V probably is similar in age to or slightly younger than the base of the Sespe Formation in Simi Valley, Ventura County, and could be laterally equivalent to the upper part of the Santiago Formation in northern San Diego County. Based on the occurrence of *Yatkolamys*, the top of the S/V probably is approximately the same age as the top of the Piuma Member of the Sespe Formation in the Santa Monica Mountains of Los Angeles County. However, the tops of the S/V and the Piuma Member are approximately 10.4 m.y. younger than the top of the upper member of the Sespe Formation in Simi Valley and the top of the undifferentiated Sespe Formation at South Mountain and along Oak Ridge in Ventura County (see Prothero et al., 1996).

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