CONTRIBUTIONS TO PALEONTOLOGY

IX

STRATIGRAPHY OF THE EASTERNMOST VENTURA BASIN, CALIFORNIA, WITH A DESCRIPTION OF A NEW LOWER MIOCENE MAMMALIAN FAUNA FROM THE TICK CANYON FORMATION

By Richard H. Jahns

With three plates and nine text figures

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Contribution No. 300

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INTRODUCTION

The great thickness of dominantly nonmarine Tertiary strata in the eastern part of the Ventura Basin has impressed geologists since the time of the earliest surveys of the region. The younger of these strata, comprising the so-called Mint Canyon formation, have been eroded to form a great basinlike area in which numerous badland exposures occur (see fig. 1). Erosion has been due principally to the poor consolidation of the sediments and in part also to the rather scant cover of typical Sonoran vegetation. Although several earlier investigators examined these badlands, the first recorded discovery of vertebrate remains came as a result of reconnaissance mapping by Kew in 1919. In the publication that followed, a provisional list of the forms found here was furnished by Stock,[1] although no detailed study of the fauna was made.

After obtaining additional materials from the Mint Canyon beds, Maxson [2] in 1930 published a detailed discussion of the fauna, and agreed with Stock on an upper Miocene age for the series. He further recognized that this vertebrate assemblage not only furnishes valuable data from which an age determination of the deposits might be made, but likewise sheds light on the age of the overlying marine strata and on their correlation with continental equivalents in the Great Basin and Great Plains provinces to the east. In a subsequent critical review of the fauna, Stirton [3] reached conclusions not in accord with those of Maxson, and advocated a lower Pliocene age for the strata. Since that time, several papers [4] of a mildly controversial nature have dealt directly or indirectly with the age of the Mint Canyon and with the stratigraphic relations of the fossils involved. The non-uniform character of the fauna, in which primitive and advanced types of mammals appear to be in association, has presented an additional

[1] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, p. 54, 1924.

[2] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, pp. 77–112, 1930.

[3] R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 26, pp. 569–570, 1933.

[4] P. Teilhard de Chardin and R. A. Stirton, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 23, pp. 277–290, 1934. R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 32, pp. 174, 188, 1936; Jour. Paleontol., vol. 13, pp. 135–136, 1939. P. O. McGrew and G. E. Meade, Amer. Jour. Sci., 5th ser., vol. 36, pp. 197–207, 1938. G. E. Lewis, Amer. Jour. Sci., 5th ser., vol. 36, pp. 208–211, 1938. J. H. Maxson, "Miocene-Pliocene boundary" (abstract), Bull. Amer. Assoc. Petrol. Geol., vol. 22, pt. 2, pp. 1716–1717, 1938. J. H. Maxson, Bull. Geol. Soc. Amer., vol. 49, no. 12, pt. 2, pp. 1916–1917, 1938. J. E. Eaton, Bull. Amer. Assoc. Petrol. Geol., vol. 23, pp. 533–534, 1939.

FIG. 1. The Mint Canyon area as viewed from Santa Clara Ridge in the San Gabriel Mountains to the southeast. The higher regions are composed of crystalline rocks; the basinlike lowlands have been eroded out of softer sedimentary rocks. Note the Vasquez and Tick Canyon beds lapping against the darker-colored granitic basement in the middle distance.

complication. Both Maxson and Stirton have commented [5] on this peculiar feature, although no stratigraphic break has been noted in the section.

That disagreement continues to exist in regard to the stratigraphy of the Mint Canyon area is not surprising, chiefly for three reasons, as follows:

1. Not only are the vertebrate remains fragmentary and poorly preserved, but there is a paucity of forms comparable to those of other known vertebrate horizons.

2. The orogenic disturbances active in this region during Tertiary time have created structural complexities, the true nature and extent of which become apparent only after detailed geologic study. Although in regions of flat-lying strata the plotting of fossil localities on a topographic map suffices to create a clear picture of the actual field relations, such a procedure in the highly folded and faulted Mint Canyon area has been of little value. Further, the irregular lateral lithologic gradations characteristic of the fossiliferous strata greatly reduce the number of available marker beds and key horizons. As a consequence, there has been a lack of definite data on the stratigraphic position of each form.

3. The generalized character of the geologic mapping previously done, as well as some confusion in the literature, has thrown doubt on the position and relations of the Mint Canyon beds and adjacent formations, particularly the overlying marine strata. That a fuller understanding of these relations is essential to a successful marine-nonmarine correlation naturally follows.

NATURE AND SCOPE OF PRESENT INVESTIGATION

In an attempt to obtain a clearer concept of Mint Canyon stratigraphy and to determine definitely the field relations between marine and nonmarine beds, the writer devoted some forty-five field days to reconnaissance observations and to detailed mapping of a "critical area" in the basin. This area is approximately 15 square miles in extent; it includes nearly all the important known vertebrate localities, many of the badland exposures most promising as potential sources of additional material, and a significant part of the contact between the Mint Canyon and overlying marine strata. The detail of the mapping has permitted a determination of the relative stratigraphic position of each fossil occurrence within narrow limits.

The collection by H. D. Curry, Dr. J. H. Maxson, and R. W. Wilson of oreodont, equid, and rodent remains from the lowermost beds of the Mint Canyon furnished the best basis for analyzing the problem of the "mixed fauna." The fossil types were kindly turned over to the writer for study by Dr. Maxson, and the results obtained are presented in this paper with newly acquired stratigraphic data. No further review of forms previously obtained from beds higher in the section is attempted, inasmuch as pertinent detailed discussions are available in the existing literature.[6]

[5] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, pp. 81, 85, 1930. R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 26, p. 575, 1933; vol. 32, p. 188, 1936.

[6] J. H. Maxson, *op. cit.*, 1930. R. A. Stirton, *op. cit.*, 1933.

ACKNOWLEDGMENTS

The present investigations were made under the direction of Dr. Chester Stock, to whom the writer is greatly indebted, not only for his invaluable advice and suggestions and his critical examination of the manuscript, but for his continued interest in all phases of the problem. Dr. J. H. Maxson made available the new fossil material from the lower Mint Canyon beds and furnished valuable information on the invertebrate fauna collected by him from the overlying marine strata. Sincere appreciation is also expressed for the advice and criticism given by E. L. Furlong and J. F. Dougherty, and by Dr. R. W. Wilson, who studied the rodents of the new fauna. L. W. Davenport, R. E. Wallace, and W. T. Potter, Jr., gave generously of their time in helpful field assistance. The illustrations have been prepared or supervised by D. P. Willoughby.

LOCATION

The easternmost portion of the Ventura Basin, discussed in this paper, is located in the northwestern part of Los Angeles County, California, and is drained by the upper Santa Clara River and its tributaries (see fig. 2). Most important of the latter are Bouquet, Mint, and Tick Canyons, which join the Santa Clara Valley on its north side. Although hilly and rough

FIG. 2. Index map of a part of southern California, showing location of the eastern part of the Ventura Basin. The stippled rectangle represents the area shown in figure 3.

in detail, the topography is rather subdued when compared with that of the San Gabriel Mountains immediately to the south. Lying within this part of the basin, in the main between Mint and Bouquet Canyons (Humphreys Quadrangle, U. S. Geol. Surv.), is the smaller area which was mapped in detail (see hachured area in fig. 3). C.I.T. Vert. Pale. Loc. 201, the quarry from which most of the new fossil material was obtained, is situated near the narrows of Vasquez Canyon, a tributary of Bouquet Canyon, at a distance of approximately 10 miles by road from Saugus, a small town on the Southern Pacific Railroad.

FIG. 3. Geologic map of a part of the Mint Canyon area, easternmost Ventura Basin; after Kew, with modifications by C. T. Smith and R. H. Jahns. The area with irregular outline in the northern part of the map and traversed by Bouquet Canyon is that shown in the large geologic map (fig. 4).

STRATIGRAPHY

General Statement

The easternmost Ventura Basin consists of a pre-Cretaceous crystalline basement complex, over part of which lies a thick section of predominantly nonmarine Tertiary sedimentary rocks. The basinlike distribution of these rocks north of the Santa Clara River makes for a general decrease in age of exposed units from the north and east to the south and west. A steadily progressive decrease in degree of consolidation of the sediments is also evident as one passes upward through the Tertiary section. Although large-scale faulting is very common in the region, a sufficient number of depositional contacts are available to prove an unconformity between each formation and the succeeding one in the accompanying chart.

Age	Unit
Pleistocene and Recent	Alluvial sands and gravels Terrace gravels
Pliocene	Saugus formation
Miocene	"Modelo" formation
	Mint Canyon formation
	Tick Canyon formation
Oligocene ?	Vasquez series
Pre-Cretaceous	Crystalline basement complex

The mammalian species collected in the lowermost Mint Canyon beds demonstrate the presence of a distinctly older horizon than has been hitherto ascribed to the series. There is necessarily implied not only a greater age range, but the presence of at least two formations within that part of the section heretofore mapped as Mint Canyon. This is corroborated by stratigraphic evidence obtained during the course of the detailed mapping. It has been suggested,[7] therefore, that the older, lowermost beds be termed the Tick Canyon formation,[8] and that for the remaining land-laid beds, which constitute the bulk of the section, the name Mint Canyon formation be retained. For the section as a whole, Mint Canyon series appears to be a suitable term, and should apply to all areas previously mapped as Mint Canyon formation but in which there is reason to suspect the presence of strata of Tick Canyon age.

[7] R. H. Jahns, Amer. Jour. Sci., 5th ser., vol. 37, p. 819, 1939.

[8] The name Tick Canyon is assigned because of excellent exposures about ½ mile down the canyon from an abandoned borax mine at the head of Tick Canyon, as well as in the vicinity of the Tick Canyon–Mint Canyon divide (Lang Quadrangle, U. S. Geol. Surv.). The type section, however, is located between Mint and Vasquez Canyons in the Humphreys Quadrangle (see figs. 3, 4).

Crystalline Basement Complex

The extreme complexity of the so-called basement complex is typical of most ancient terranes in which metamorphic rocks have become intimately associated with later igneous intrusives. One large exposure of these rocks, a westward prong of the Sierra Pelona (see fig. 1), appears in the Mint-Bouquet Canyon area. The dominant type is the fine-grained, bluish-gray rock known as the Pelona schist; with it are associated minor amounts of quartzite, hornblende-rich schist, and phyllite. Into the metamorphics has been injected much granitic material, giving rise to many masses of migmatitic rocks. Chief among these are "spotted diorites" and porphyroblastic gneisses. A few small bodies of syenite and granodiorite are also present. Little can be said concerning the age of these rocks except that they are considered as pre-Cretaceous, a view based on their injection by supposedly Sierran plutonics.

Vasquez Series

Cropping out in a large area between Bouquet and Vasquez Canyons are the coarse, light-colored sandstones and conglomerates doubtfully referred by Kew [9] to the Sespe, but called the Escondido series by Hershey [10] and Simpson.[11] More recently, Sharp [12] has suggested the name Vasquez in place of Escondido, which is preoccupied; his usage is followed in this discussion. These coarse, massive sediments are faulted against the basement complex in Vasquez Canyon, but lie with depositional contact upon the crystallines in the type area to the east (Ravenna Quadrangle, U. S. Geol. Surv.). South and east of Mint Canyon these deposits increase in coarseness and degree of consolidation, and appearing with them are interbedded flows and sills of andesite and basalt. A distinct reddish color becomes characteristic.

Available data indicate a localized fault-block basin of deposition for the 9000 feet of Vasquez beds, with transportation of material subaerially for short distances from rather steep source slopes. The general trend of deposition was westward, with a gradual decrease in detrital coarseness in that direction. Intermittent periods of volcanic activity produced an additional 4000 feet of basic flows and shallow concordant intrusions. The exact age of the series is shrouded in doubt. Because all attempts to find fossils in the more promising strata have proved unsuccessful, the various postulated ages of Eocene, Oligocene, and middle Miocene have been based on non-paleontological evidence. A doubtful Oligocene assignment is here made; a detailed discussion follows in the section dealing with the age of the Mint Canyon.

[9] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, pp. 38–39, 1924.
[10] O. H. Hershey, Amer. Geologist, vol. 29, pp. 349–372, 1902.
[11] E. C. Simpson, Calif. Jour. Mines and Geol., vol. 30, pp. 391–395, 1934.
[12] R. P. Sharp, Pan Amer. Geologist, vol. 63, p. 314, 1935.

Tick Canyon Formation

The basal beds of Hershey's Mellenia series [13] and Kew's Mint Canyon formation [14] are traceable in a narrow, irregular band extending from the Tick Canyon area northwesterly to a point between Vasquez and Texas Canyons, where lack of exposures prevents their demarcation from the overlying Mint Canyon strata. At the type section near locality 201 (locality *Bt* on geologic map, fig. 4) the formation consists of 593 feet of reddish-brown clay, siltstone, and sandstone, with a thick, irregular zone of poorly lithified boulder to cobble conglomerate at the base (see measured section on page 163). Nearly everywhere else, it is much thinner, with an average thickness of approximately 350 feet; in at least one locality, it appears to wedge out entirely between the Mint Canyon and the basement complex. The fine-grained, evenly laminated character of certain beds, as well as the local worm borings which the sediments contain, suggests a lacustrine origin; the bulk of the section, however, is fluviatile.

For a distance of more than a mile between Mint and Vasquez Canyons, the very coarse basal beds of the Tick Canyon formation lap against the basement complex on a steeply dipping depositional contact. The attitude and coarseness of these beds, as well as the angularity and lack of sorting of their contained fragments, indicate deposition at the base of a very steep slope, with transportation of sediment for only a limited distance. Similar relations exist between the Tick Canyon and the Vasquez series, although the contact is not so clearly exposed. That at least a part of the Vasquez formed highlands during Tick Canyon time is shown by the presence in the latter of fragments of a peculiar volcanic breccia characteristic only of the upper Vasquez.

Mint Canyon Formation

Inasmuch as the Mint Canyon beds have an aggregate thickness of about 4000 feet, and have generally less steep attitudes than either of the above-noted formations, it is scarcely surprising that the exposures of this formation have a considerable areal extent (see fig. 3). Its general lithologic characters have been discussed by Kew [15] and Maxson,[16] who indicated a division of the section into two main parts. For purposes of structural interpretation and stratigraphic location, the writer has made a 27-fold subdivision of the Mint Canyon formation. Each member represents a time, rather than lithologic, unit, and its distribution has been traced, so far as possible, by marker beds or exposures sufficiently clear for recognition as time boundaries within areas of changing lithology. The following measured section illustrates the typical distribution of rock types throughout the 27 members; their areal pattern appears on the geologic map (fig. 4).

[13] O. H. Hershey, *op. cit.*, pp. 356–358, 1902.
[14] W. S. W. Kew, *op. cit.*, p. 52, 1924.
[15] *Ibid.*, pp. 52–53, 1924.
[16] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, p. 81, 1930.

FIG. 4. Detailed geologic map of a part of the Mint Canyon area

MEASURED SECTION OF TERTIARY FORMATIONS FROM BOUQUET CANYON NEAR THE NEW ERA SCHOOL TO UPPER VASQUEZ CANYON, VIA PUCKETT MESA, CALIFORNIA

(Section is composite, with all matched parts from areas no more than ¼ mile apart in the field.)

	Thickness (feet)	
SAUGUS FORMATION		
Sandstone and silt, rusty brown and pinkish, poorly consolidated, irregularly bedded, with local lenses of very coarse gravel	30+	
Conglomerate, light gray, sandy, cross-bedded, poorly cemented	4	
Sandstone, as above, with brownish schist-rich zones and beds of pink and red clay; poorly exposed	120	
Total thickness, Saugus formation		154+
Unconformity		
"MODELO" FORMATION		
Shale, sandy, buff to brown, thin-bedded, with reddish-brown concretionary structures	14	
Sandstone, buff and tan, arkosic, very friable, locally gypsiferous, with small reddish-brown clastic dikelets	45	
Shale, gray to brown, sandy, with minor sandstone beds	11	
Pebble conglomerate, gray to tan, well bedded, gypsiferous	13	
Sandstone, as above, with intercalated shale and conglomerate lenses	22	
Sandstone, light gray, massive, very friable	17	
Shale, greenish gray to reddish brown, sandy, gypsiferous, locally rich in concretions, clastic dikelets, and charcoal; breaks into small blocks	56	
Sandstone, gray to brown, arkosic, friable, poorly exposed	159	
Sandstone, light gray, massive, with minor shale	134	
Cobble conglomerate, light brown, evenly bedded, very gypsiferous, with fragments of quartz, granitic and schistose rock types, silicic and intermediate volcanics, and Mint Canyon sandstone in an arkosic matrix; forms cliffs and is a good marker horizon	16	
Total thickness, "Modelo" formation		487
Unconformity		
MINT CANYON FORMATION		
Member 27		
Sandstone, buff to gray, well sorted but with local pebble lenses, and siltstone, greenish gray, blocky, alternating in thin layers; the whole weathers to sandy or gravelly slopes	115+	
Conglomeratic sandstone, creamy to light gray, cross-bedded, massive, broadly lenticular, with minor intercalated blocky pinkish siltstone; locally cliff-making	32	

MINT CANYON FORMATION—*Continued*		Thickness (feet)
Conglomerate, heavy and massive, rich in pebbles and cobbles of andesite and andesite breccias; forms distinct cliff	7	
Total thickness, member 27		154+
Member 26		
Conglomeratic sandstone, light gray, and siltstone, greenish gray to buff, blocky, not massive, alternating in thick layers with the latter subordinate; locally resistant	28	
Siltstone and clay, dominantly buff, pinkish, and greenish, sandy, well bedded; scattered vertebrate fossils	38	
Pebble conglomerate, continuous, moderately well sorted, rich in subrounded andesite and schist fragments	5	
Total thickness, member 26		71
Member 25		
Sandstone, silty and locally pebbly, creamy gray, with intercalated thin, hard, persistent, flaggy brown arkosic sandstone; forms smooth-faced cliffs	71	
Vitric tuff, friable, pearly gray with bluish cast, medium-grained, granular but not gritty; associated with tuffaceous sandy beds; exposed only locally	4	
Total thickness, member 25		75
Member 24		
Conglomerate, very sandy, creamy gray, blocky, with sandy lenses; forms cliffs	5	
Siltstone and clay, brown, tan, and pinkish, with flaggy interbeds of hard brown sandstone; scattered vertebrate remains (C.I.T. Loc. 101)	17	
Cobble conglomerate, brown to gray, well bedded, rich in fragments of basement complex; forms vertical, smooth-surfaced cliffs	23	
Siltstone and clay, as above	34	
Cobble conglomerate, white to gray, otherwise as above	13	
Total thickness, member 24		92
Member 23		
Siltstone, locally sandy and pebbly, tan, gray, pink, and brown, with subordinate conglomerate, coarse-grained, creamy gray to white, rich in andesite and granite fragments; the whole poorly exposed	240±	
Vitric tuff, granular, fine- to medium-grained, bluish gray, in part friable; highly lenticular and poorly exposed	3	
Sandstone, hard, brown, irregularly jointed, arkosic, and with local mafic-rich lenses	2	

		Thickness (feet)
Conglomerate, poorly cemented, coarse-grained, rich in andesite, volcanic breccia, and schist fragments, with sandstone and sandy siltstone, white to buff, weathering into soily slopes; upper part poorly exposed	82	
Vitric tuff, as above	4	
Sandstone, hard, brown, as above	2	
Total thickness, member 23		333±
Member 22		
Boulder conglomerate, gray, massive, poorly sorted, resistant	14	
Sandstone, gray, coarse, and conglomeratic, regularly bedded, with local lenses of light gray cobble conglomerate; cliff-making horizon	35	
Siltstone, tan to gray, sandy, blocky; blocks exfoliate, then crumble to soily masses; irregularly fossiliferous (C.I.T. Loc. 99)	42	
Cobble and pebble conglomerate, cross-bedded, light gray to white, with associated channel sandstones, gray, friable, lenticular	28	
Total thickness, member 22		119
Member 21		
Siltstone, pinkish, tan, and greenish gray, with sandy lenses rich in clay nodules; scattered beds of conglomeratic sandstone, well sorted, vertically jointed, resistant	33	
Sandstone, arkosic, coarse, well sorted, with subordinate siltstone, tan and greenish; forms cliff	24	
Sandstone, creamy gray, massive, resistant, with silty partings	11	
Total thickness, member 21		68
Member 20		
Siltstone, buff, bluish gray, and pinkish, sandy, evenly bedded, and sandstone, conglomeratic, massive, cliff-making, alternating in thick layers; forms local badlands with scattered vertebrate fossils	91	
Vitric tuff, bluish gray, friable to blocky, lenticular, poorly exposed	3	
Sandstone, brown, hard, ripple-marked, flaggy	3	
Total thickness, member 20		97
Member 19		
Siltstone, light gray to tan, evenly bedded, with thin sandy and pebbly layers; forms smooth-faced vertical cliffs	58	
Sandstone, pebbly, light gray, cross-bedded, well sorted, massive	8	

MINT CANYON FORMATION—*Continued*		Thickness (feet)
Siltstone, light gray to pinkish brown, regularly bedded, with few resistant layers; forms badlands, sparsely fossiliferous (C.I.T. Loc. 102)	51	
Total thickness, member 19		117
Member 18		
Conglomerate, heavy, massive, coarse, locally sandy	12	
Sandstone, poorly consolidated, with siltstone, light gray, thinly bedded; much less resistant than conglomerate above	34	
Total thickness, member 18		46
Member 17		
Crystal tuff, medium-grained, white to buff, delicately bedded, with associated tuffaceous sandstone; whole weathers into angular blocks	3	
Sandstone, arkosic, hard, coarse, brown, flaggy	2	
Conglomerate, light gray, heavy, resistant, with rounded pebbles and cobbles of andesite, schist, and granitic rocks; minor interbeds of sandy siltstone	38	
Crystal tuff, as above; lenticular and poorly exposed	2	
Sandstone, gray and tan, well sorted, evenly bedded, and siltstone, brown to gray, blocky, weathering into gritty soil; alternate in 1- to 6-foot layers and form steep, corrugated cliffs	55	
Conglomerate, as above	15	
Siltstone, very gritty, light gray, locally rich in clay nodules	14	
Total thickness, member 17		129
Member 16		
Pebble conglomerate, white to gray, evenly but massively bedded; weathers to gravelly slopes but forms local cliffs	23	
Siltstone, sandy to pebbly, gray; forms fluted cliffs and badlands with scanty vertebrate remains (C.I.T. Loc. 100)	58	
Conglomerate, bouldery, poorly cemented, associated with channel sandstones	12	
Total thickness, member 16		93
Member 15		
Crystal tuff, snow white to buff, ripple-marked, delicately bedded, weathering into angular blocks; local tuffaceous sandstone, bearing plant fossils	4	
Sandstone, brown, hard, flaggy	3	
Sandstone, light gray, friable, rich in clay nodules, and local brown, flaggy arkose; subordinate siltstone, pearl gray, weathering blocky	89	

		Thickness (feet)
Boulder conglomerate, crudely bedded, cross-bedded, poorly sorted; shows cut-and-fill channel structure..	6	
Total thickness, member 15		102
Member 14		
Crystal tuff, as in member 15	3	
Sandstone, brown, hard, flaggy	2	
Siltstone, very sandy, greenish to tan, and pebbly sandstone, alternating in thick layers; local vertebrate fossil accumulations (C.I.T. Loc. 103, Los Angeles Museum Loc. 1006)	15	
Sandstone, massive, friable, vertically jointed	3	
Siltstone, as above	19	
Conglomerate, typical stream-channel type	7	
Siltstone, fine-grained, yellowish to greenish gray, locally rich in vertebrate fossils (Univ. of Calif. Loc. 3564)	58	
Sandstone, bluish gray, friable, persistent	1	
Total thickness, member 14		108
Member 13		
Sandstone and siltstone, light gray, alternating regularly in 1- to 4-foot layers; form cliffs of corrugated appearance	27	
Cobble conglomerate, cross-bedded, poorly sorted, with channel-filling structures	4	
Sandstone, silty, buff to gray, friable, poorly exposed..	17	
Sandstone, tan, massive, vertically jointed	5	
Total thickness, member 13		53
Member 12		
Siltstone, tan, buff, and gray, locally very sandy, with scattered interbeds of hard, flaggy brown sandstone; very poorly exposed, weathering to sandy slopes....	113	
Crystal tuff, with much tuffaceous sandstone, white to light gray, hard to crumbly	2	
Total thickness, member 12		115
Member 11		
Siltstone and clay, light green, tan, pinkish, buff, and purplish, evenly and thinly bedded, highly gypsiferous, with a few flaggy interbeds of hard, brown arkosic sandstone	88	
Sandstone, buff to light gray, well sorted, very resistant	5	
Total thickness, member 11		93
Member 10		
Clay, highly colored in greens, buffs, and pinks, gypsiferous, with flaggy beds of hard brown sandstones...	27	

MINT CANYON FORMATION—*Continued*		Thickness (feet)
Siltstone and clay, dominantly gray and brownish, with interbeds of papery brown sandstone	68	
Clay, as above	24	
Sandstone, brown, friable, tending to massive	4	
Crystal tuff, white to gray, lenticular, with much tuffaceous sandstone	1	
Total thickness, member 10		124
Member 9		
Clay, dark gray to black, crumbly	3	
Siltstone, gray to buff	11	
Siltstone, brown to maroon, with flaggy interbeds of hard brown sandstone	15	
Sandstone, light gray, blocky, impure	4	
Siltstone, maroon, gypsiferous, clayey	30	
Sandstone, as above	30+	
Sandstone, white to tan, and clayey siltstone, buff to maroon, alternating in thin beds; lower part poorly exposed, sparsely fossiliferous (Univ. of Calif. Loc. 3571)	142+	
Total thickness, member 9		235+
Member 8		
Siltstone, gray, clayey	15	
Siltstone, pearl gray, brown, and greenish, gritty	14	
Sandstone, tan, blocky, with conglomerate zone at base	5	
Conglomerate, light gray, well bedded, with silty matrix	17	
Sandstone, gray, coarse, arkosic, with minor pebble conglomerate, rich in fragments of granitic crystallines, andesites, and volcanic breccias; whole weathers to sandy and gravel-strewn slopes	87	
Total thickness, member 8		138
Member 7		
Siltstone, light tan to pinkish, thinly bedded, weathering into soily slopes	43	
Sandstone, arkosic, brown, blocky to flaggy	3	
Siltstone and sandstone, tan and gray, fine to coarse, the whole very heterogeneous	46	
Sandstone, as above	3	
Siltstone, sandy, white to pinkish, seriate but generally fine-grained	41	
Conglomerate, white, poorly cemented, well stratified, with cobbles of the usual igneous rocks	5	
Siltstone, sandy, as above	46	
Siltstone, sandy to clayey, dominantly pinkish, fine-bedded; forms local badlands	10	
Total thickness, member 7		197

		Thickness (feet)
Member 6		
Siltstone, pinkish, and sandstone, whitish, interbedded intimately; rich in clay nodules and vivianite smears; the whole nonresistant and poorly exposed, with local badlands carrying scattered vertebrate remains (Univ. of Calif. Loc. 3555)	138	
Sandstone, tan to gray, friable, arkosic; weathers to soily slopes	104	
Conglomerate, chalky red, massive with sandy lenses, locally cross-bedded; prominent marker bed but not persistent	9	
Sandstone, as above	49	
Conglomerate, white, poorly cemented, with rounded cobbles of granitic rocks	4	
Siltstone and clay, pearl gray, smoky gray, tan, pink, purple, and brown, heavily gypsiferous, fine-grained, thin-bedded, rich in white clay nodules; locally forms badlands	152	
Total thickness, member 6		456
Member 5		
Sandstone, light gray to tan, very impure, poorly cemented, with many resistant flaggy beds, arkosic, brown, very evenly spaced in section	145	
Clay, greenish, tan, purple, pinkish, buff, and brown, gypsiferous, and conglomerate, light brown, alternating fairly regularly; whole becomes very red locally	26	
Total thickness, member 5		171
Member 4		
Sandstone, white, coarse, friable	4	
Clay and siltstone, greenish, pinkish, tan, brown, and dark gray, gypsiferous; forms slumped slopes and isolated badlands	56	
Siltstone, pinkish to brownish, blocky, with thin, resistant, flaggy sandstone lenses; bears scanty vertebrate fossil remains	83	
Sandstone, brownish, impure, friable, poorly exposed	75	
Cobble conglomerate, brown, well cemented, well stratified, cross-bedded; forms cliffs	8	
Total thickness, member 4		226
Member 3		
Sandstone, reddish brown, massive, impure, and pebble conglomerate, thinly bedded, well cemented, alternating in thick layers	52	
Siltstone, gray to tan, blocky, with flaggy sandstone, thin, brown, arkosic	51	
Sandstone, as above	145	

		Thickness (feet)	
MINT CANYON FORMATION—*Continued*			
Pebble conglomerate, chalky reddish brown, massive, well cemented, locally sandy, rich in schist fragments; forms cliff	15		
Sandstone, reddish brown to ocherous, arkosic, with minor pebble conglomerate and siltstone	112		
Pebble conglomerate, chalky reddish brown, well sorted, evenly stratified, locally cross-bedded, moderately well cemented, with local lentils of arkosic sand; forms ridges and cliffs	27		
Total thickness, member 3		402	
Member 2			
Siltstone, brown and reddish brown, sandy, poorly exposed	34		
Conglomerate, light gray, poorly cemented, well bedded	11		
Sandstone, reddish brown, conglomeratic, arkosic, friable, poorly exposed	87		
Conglomerate, gray to brownish, thinly but irregularly bedded, persistent, resistant, rich in schist fragments	4		
Total thickness, member 2		136	
Member 1			
Conglomerate, chalky brown, heavily bedded, rich in flaggy schist fragments, and conglomeratic sandstone, friable, arkosic, alternating in 6- to 10-foot layers; whole forms local cliffs	94		
Total thickness, member 1		94	
Total thickness, Mint Canyon formation			4044±
Unconformity			
TICK CANYON FORMATION			
Sandstone, uniformly reddish brown, friable, with minor silty and soily beds; poorly exposed, but forms badlands locally		158	
Conglomerate, tan to reddish brown, cross-bedded, poorly cemented		6	
Sandstone, as above; siltstone, ocherous to reddish brown, thinly laminated, gypsiferous; and scattered thin beds of sandy shale, compact, reddish to greenish brown, with casts of worm borings		110	
Conglomerate, light gray, poorly consolidated, pebbles and cobbles subrounded, white arkosic cement		12	
Sandstone, as above, but with more pebbly and flaggy beds		68	
Siltstone, reddish brown, compact, evenly and thinly bedded, with minor flaggy sandstone and greenish clay; locally fossiliferous (C.I.T. Loc. 201)		55	
Clay and siltstone, red, tan, olive green, yellow, and brown, fine-grained, highly gypsiferous, poorly exposed		75	
Sandstone and arkose, reddish brown, crumbly, poorly sorted		15	

	Thickness (feet)	
Cobble to boulder conglomerate, tan to gray, poorly bedded, sorted, and lithified, with large fragments of underlying basement rocks	94	
Total thickness, Tick Canyon formation		593

Unconformity

BASEMENT COMPLEX

Mica schist, syenite, granodiorite, quartzite, and miscellaneous migmatitic rock types

TOTAL THICKNESS OF SEDIMENTARY SECTION	5278±

It will be noted that the beds in the lower half of the section (members 1 to 11) are characteristically fine-grained, thin-bedded, and of variegated colors, whereas those higher up are more irregular, coarser, and subdued in color. Vertebrate remains seem to occur in horizons having a rather even vertical distribution, although the upper horizons yield a greater abundance of material. Another gradation of unusual interest is that between the coarse fluviatile sandstones and conglomerates adjacent to Puckett Mesa on the southeast and their fine-grained, evenly bedded lacustrine counterparts to the northwest. This is particularly well shown at the base of member 15, where within a distance of a half-mile a heavy channel conglomerate passes laterally without break through a littoral sandstone zone into thinly bedded lacustrine silts and clays. That such a relation actually exists is demonstrated by a prominent light-colored marker bed of waterlaid tuff, which lenses out immediately beneath the conglomerate. The relative distribution of fluviatile and lacustrine strata in the vicinity of Bouquet Canyon is shown in figure 5; section *CD* in figure 6 illustrates the gradational phenomenon mentioned above.

Greenish to gray silty beds in the lacustrine section contain numerous fresh-water gastropod remains, chief among which is the species *Paludestrina imitator* Pilsbry.[17] Localities where these mollusks are conspicuous are recorded in figures 4 and 5. The occasional vertebrate fragments found with them are confined to the margins of the large lacustrine basin (see fig. 5). Detailed mapping of the silty deposits, especially their tracing across the broadly alluviated Bouquet Canyon, was made possible by the presence in the section of several marker beds of white to gray tuff and tuffaceous sandstone. These beds, because they are confined in their extent to the regions of soft lake deposits, stand out clearly and form the ridges in the present topography.

The Mint Canyon formation overlies the older Tick Canyon in all places where the latter is exposed. In the vicinity of locality 201 an angular unconformity is suggested between the two; two small folds and associated

[17] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, p. 54, 1924.

FIG. 5. Outline of that portion of the Mint Canyon region mapped in detail (see fig. 4), showing structural axes and distribution of faunal types.

FIG. 6. Structure sections across parts of the Mint Canyon area (see fig. 4 for exact locations).

minor plications in the fine-grained older beds do not appear in the superjacent conglomeratic strata of the Mint Canyon formation. This feature, however, might be merely the result of differences in competence of the two rock types. That a sedimentary break indicated by the faunal differences does appear, probably as a disconformity, is shown by the location of the contact at the base of a thick conglomerate zone, a location fixed with certainty by fossil occurrences. Its unconformable nature is further shown by a general change in lithology (see measured section or section *GH*, figure 6) and by the irregular distribution of the Tick Canyon beds. Where these strata are not exposed, the Mint Canyon nonconformably overlies the Vasquez series, or is faulted against older rocks.

"Modelo" Formation

Above the Mint Canyon lie the fossiliferous brownish sandstones and shales tentatively correlated with the Modelo by Kew.[18] Although they are equivalent to the upper part of the Modelo group, these beds are herein termed "Modelo" because they do not correspond in age to the Modelo, *stricto sensu*, of Hudson and Craig.[19] They were deposited under brackish-water and marine conditions, and are the only marine beds in the easternmost Ventura Basin north of the Santa Clara Valley. The "Modelo" is exposed over a broad area in the higher hills between Haskell and Bouquet Canyons, but pinches out between Mint Canyon strata and the overlying Saugus formation on the south side of the latter canyon.

Although Kew recorded a pronounced nonconformity between the marine and the underlying nonmarine strata, it has since been suggested [20] that the relation is one of interfingering or lateral and upward intergrading, due presumably to marine transgressive overlap. The resulting confusion has thrown serious doubt on the exact stratigraphic relations between the "Modelo" invertebrates and the Mint Canyon vertebrate horizons. That the features of the Bouquet-Haskell Canyon contact area are in no way attributable to interfingering or gradation of the type suggested, but are on the other hand characteristic of a true unconformity is denoted by the following cogent facts:

1. The base of the "Modelo" is marked by a persistent, evenly bedded cobble conglomerate member which contains fragments of Mint Canyon material. Throughout the area this conglomerate remains of surprisingly uniform thickness and is quite distinct from the underlying siltstones of the Mint Canyon formation. Its bedding is everywhere parallel with its trend.

2. Although the post-"Modelo" age of much of the folding in the Mint Canyon has resulted in essentially concordant relations between the two

[18] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, pp. 67–69, 1924.

[19] F. J. Hudson and E. K. Craig, Bull. Amer. Assoc. Petrol. Geol., vol. 13, pp. 509–518, 1929.

[20] T. Clements, Bull. Amer. Assoc. Petrol. Geol., vol. 21, p. 215, 1937. R. A. Stirton, Jour. Paleontol., vol. 13, chart on p. 135, 1939.

formations, there are local discrepancies of attitude. Non-conformability is especially well shown on the west side of Haskell Canyon.

3. The detailed mapping has revealed a north-northeastward convergence between the two formations amounting to about 200 feet in a half-mile. In the absence of interfingering in the area, this feature is suggestive of a post-Mint Canyon pre-"Modelo" southwestward tilting and a subsequent erosion interval.

4. As pointed out by Clements,[21] the Mint Canyon formation does thin to the northwest. This thinning, however, is accomplished by the loss of *basal* members, probably because of an approach to a landward margin of the Mint Canyon basin of deposition. It appears likely that any marine interfingering in which the Mint Canyon has a part is to be found toward the *west* and *southwest*, not toward the northwest.

On the basis of invertebrates determined by Clark [22] and Woodring [23] as *Amphyssa* sp., *Ostrea titan*, *Pecten crassicardo*, *Pecten raymondi*, and *Astrodapsis* cf. *tumidus*, an upper Miocene age was assigned to the "Modelo." An invertebrate collection subsequently made by Maxson and identified by U. S. Grant IV [24] substantiates this age determination and justifies a more specific correlation with the uppermost Miocene Neroly. In addition to the forms given above, those determined by Grant include:

Terebratalia occidentalis
Terebratalia occidentalis obsoleta
Anadara osmonti
Anadara obispoana
Aequipecten discus
Lyropecten crassicardo
Lyropecten cf. estrellanus
Astrea aff. ? brangulata
Polinices sp.
Tegula sp.

Rather meager foraminiferal evidence reported by Hughes [25] further strengthens a Neroly age assignment. Thus, the Mint Canyon vertebrate horizons are older than the uppermost Miocene of the Pacific coast marine sequence.

Saugus Formation

The Saugus formation rests unconformably on the "Modelo" and Mint Canyon strata, and represents extensive deposition on a broad, westward-dipping floodplain or alluvial-fan series. Its beds are light gray to reddish

[21] T. Clements, *loc. cit.*, 1937.

[22] W. S. W. Kew, *op. cit.*, pp. 68–69, 1924.

[23] W. P. Woodring, "Age of the Modelo formation of the Santa Monica Mountains, California" (abstract), 28th Ann. Meeting, Cordilleran Section, Geol. Soc. Amer., Stanford University, California, 1929.

[24] J. H. Maxson, from paper entitled "Miocene-Pliocene boundary," 15th Ann. Meeting, Pacific Section, Amer. Assoc. Petrol. Geol., Los Angeles, California, November 3, 1938.

[25] R. M. Kleinpell, Miocene stratigraphy of California, p. 71. Amer. Assoc. Petrol. Geol., 1938.

brown, crudely stratified, and poorly consolidated. Mainly unsorted sands and conglomerates, they reflect the nature of the terranes from which they were derived. Fragments of the basement complex are most common, but silicic and intermediate volcanics are far from rare. Occasionally a mass of "Modelo" or Mint Canyon sandstone appears. Although these continental beds are generally nonfossiliferous, their marine analogues to the west yield invertebrates of late Pliocene and early Pleistocene affinities.

Quaternary Deposits

Terrace deposits of Pleistocene age are not uncommon, especially on the north side of Bouquet Canyon and in an ill-defined zone peripheral to the exposed basement complex between Vasquez and Mint Canyons. These rather flat-lying deposits consist of angular, unsorted gravelly material, commonly rich in fragments of schist, granitic rocks, and other types characteristic of the basement complex. Derivation from the latter under flood-plain conditions seems certain in this part of the basin. Although their typical form is locally obscured by later stream dissection, the terrace deposits are easily recognized by their predominant reddish-brown color, rather flat-lying attitude, and limited thickness. Although individual terraces (as they now occur) may have been formed at slightly different times, they all are Pleistocene in age.

More recently deposited alluvium forms broad flats in all the larger canyons and extends up the smaller ones as narrow tongues. It is generally made up of flat-lying sands and gravels of light gray color and varying degrees of coarseness, and is dissected to a limited extent by the present streams.

GEOLOGIC STRUCTURE

Evidences of crustal movements in the Mint Canyon area are widespread and well defined. No attempt has been made to interpret the intricate structural features found in the basement complex, but of post-Cretaceous orogeny a fairly clear picture can be obtained. In addition to the post-"Modelo" and post-Saugus periods of deformation characteristic of southern California, there is evidence of extensive faulting in the early Tertiary (late Eocene?), folding and faulting in post-Vasquez, pre-Mint Canyon time, and folding following deposition of the Mint Canyon formation. The early Tertiary structures seem to reflect tensional forces, and those of later age compression and shear; exceptions, however, are not uncommon.

In spite of the intense compressional forces indicated by certain of the faults, nearly all the folds are broad and open. The very competent Vasquez strata are little folded except in upper Tick Canyon, where the finer, softer beds which appear in the uppermost part of the section attain dips of 80° or more. Those of the Mint Canyon series, on the other hand, have been thrown into a great number of subdued flexures of prevailing east-west trend and shallow westward plunge (see fig. 5). North of Bouquet Canyon

is an area of more acute folding, the convolutions of two tuffaceous beds serving admirably as structural guides. Maximum dips are about 65°. Immediately to the southwest the "Modelo" is broadly folded with the usual east-west trend. Post-Modelo strata retain their original attitudes in the area mapped, but the Saugus is warped and folded a few miles to the south and west.

Faulting presents a more complex problem. Little is known of the early Tertiary faults, except that they presented sufficient vertical movement before and probably during at least a part of Vasquez deposition to demarcate a local basin deep enough to receive some 9000 feet of coarse sediments. In the region to the east, there is some evidence that these early faults were of the tensional block type, with dips of 65° or more. The close of Vasquez deposition ushered in a period of profound crustal movement, during which the older faults became active once more and new steeper fractures developed. Both normal and reverse movements occurred. The Vasquez-basement fault in Vasquez Canyon was a product of this orogenic period. Following the inception of Mint Canyon deposition, these faults experienced relatively little movement. The third period of faulting may be considered post-Mint Canyon, pre-Saugus, and resulted in fractures of northwest trend, steep dip, and dominantly strike-slip movement. In all cases, their northeast sides have moved north; they appear to have a gash fracture relation to the San Andreas rift, which lies several miles to the north. It is of interest that they cut and offset folds in the Mint Canyon formation wherever the two features occur in juxtaposition. That Pleistocene or even younger movements have occurred is evidenced by local offsets in the terrace deposits; such movements, however, have been of very slight extent.

AGE OF DEPOSITS

Tick Canyon Formation

The mammalian assemblage obtained from the Tick Canyon beds furnishes an independent means of reaching an age assignment. Inasmuch as a detailed discussion of the faunal relations appears elsewhere in this paper, it suffices at this point to note a similarity in stage of evolution between the species from the Tick Canyon and those from the lower Hawthorn formation of Florida and from the upper Harrison and upper Rosebud formations of Nebraska and South Dakota. A comparison with these faunas, as well as with others, presents evidence strongly favoring a late lower Miocene or earliest middle Miocene age. The Tick Canyon formation is thus placed in a position stratigraphically below that of the Merychippus zone at Coalinga and slightly below that of the Phillips Ranch horizon. Its marine time equivalent is probably the lower part of the Temblor as that term is broadly used, and upper-middle Temblor of the type section (see fig. 7).

Vasquez Series

The presence of a lower Miocene horizon unconformably above the Vasquez series introduces a feature not in accord with certain age assignments made for the latter series in the past. Although Kew [26] proposed an Oligocene (?) age, middle Miocene has been advocated by other investigators, notably W. J. Miller [27] and Simpson.[28] The arguments advanced to support this contention are:

1. The lavas interbedded with the Vasquez strata are typical of those extruded over broad areas in the western United States during the middle Miocene.
2. A strong resemblance exists between the Vasquez and the middle Miocene Topanga formation, not only in the associated volcanics, but in thickness and lithology.
3. The Vasquez seems to be a correlative of the middle Miocene Rosamond formation of the Mojave region.

The relation of the Vasquez to the lower Miocene Tick Canyon formation should constitute compelling enough evidence against a middle Miocene age determination for the former. Moreover, the writer feels that none of the above arguments furnishes evidence sufficiently strong to stand in the face of paleontologic data, indirectly applied though they may be. Granting a preponderance of volcanic activity during the middle Miocene, a possibility of earlier activity is not thereby precluded, particularly since such instances have been recorded.[29] Furthermore, the lavas of the Vasquez are mineralogically different from all others known from Los Angeles County,[30] a feature which is particularly noticeable in a comparison with the Rosamond formation. Finally, any correlation with the Topanga, no matter how tentative, is subject to serious error. The Topanga is marine and the Vasquez continental, so that a correspondence in total thickness or lithology is probably coincidental. The origin of the Vasquez as a fluviatile accumulation in a highly localized basin invalidates most correlations based on lithologic character, thickness, or probable prevailing climatic conditions.

The Vasquez is unconformably underlain by the lower Eocene Martinez formation in the Tejon Quadrangle to the west. The age possibilities are thus restricted to lower Miocene, Oligocene, and upper Eocene, essentially the age range of the Sespe. Although the Vasquez beds may never have been directly connected with the whole or any part of the Sespe, they probably were laid down in a somewhat similar topographic environment during a period corresponding to at least a part of the Sespe. An Oligocene age is tentatively assigned to the series, pending the discovery of fossil remains,

[26] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, pp. 38–39, 1924.
[27] W. J. Miller, Univ. Calif. at Los Angeles Publ., vol. 1, 1934.
[28] E. C. Simpson, Calif. Jour. Mines and Geol., vol. 30, pp. 391–395, 1934.
[29] R. D. Reed, Bull. Amer. Assoc. Petrol. Geol., vol. 21, pp. 549–559, 1937.
[30] Y. Bonillas, personal communication.

although the associated flows suggest a time range extending into the lower Miocene.

Mint Canyon Formation

Because of previous discussions by Maxson,[31] Stirton,[32] and others, the fauna of the Mint Canyon formation need not be examined in detail at this time. Aside from disagreements on the exact nature of certain forms, the principal contentions appear to relate to the presence of *Hipparion,* Maxson favoring the theory of the appearance of the genus in the Miocene and Stirton holding the view that it is confined to the Pliocene. The question of utilization of *Hipparion* as a criterion of Pliocene age for the beds in which it occurs is one of world-wide application, and has brought forth discussion in Europe and Asia as well as in America. This genus has served as a basis for transoceanic correlation because of its wide and rapid dispersal from a probable American source. In this respect, its presence should be accepted as furnishing a more conclusive criterion than that of any late Tertiary invertebrate genus.

Because of the incompleteness of the original European section of the Tertiary as defined by Lyell and Deshayes, the critical Pontian and Sarmatian stages and their faunas were not included in the succession. Disagreement has subsequently arisen among European paleontologists with regard to the exact position of the Miocene-Pliocene boundary, as well as with regard to the relations of the invertebrate and vertebrate fossils employed in determining this boundary.[33] At present there is no unity of opinion as to the exact age of the type *Hipparion*-yielding strata. Nor are the stratigraphic relations of the beds containing *Hipparion* always clear. For Europe, then, the question is still unsettled.

Although at least the upper part of the Mint Canyon formation admittedly yields a fauna of undeniably lower Pliocene affinities (based on standards established by some vertebrate paleontologists), the bulk of the available evidence seems to favor a sensibly older assignment. The concept of a strict *Hipparion*-Pliocene affinity, together with the clear-cut unconformity between the Mint Canyon and overlying uppermost Miocene marine "Modelo," furnishes a striking example of the peculiar situation recognized by Reed and Hollister,[34] in which "the Lower Pliocene of most vertebrate paleontologists is at least in part the equivalent of the Upper Miocene of the invertebrate paleontologists." The confusion resulting from such conflict of views can be eliminated only by a change in age standards of either

[31] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, 1930.

[32] R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 26, pp. 569–576, 1933.

[33] G. H. R. von Koenigswald, Zentralbl. f. Mineral., pt. B, pp. 42–48, 1931. E. Stolley, Zentralbl. f. Mineral., pt. B, pp. 191–207, 1938. E. Stromer, Bayer. Akad. d. Wiss., Math.-naturwiss. Abt., vol. 32, pp. 1–20, 1938. H. Tobien, Deut. geol. Gesellsch. Ztschr., vol. 90, pp. 177–192, 1938.

[34] R. D. Reed and J. S. Hollister, Structural evolution of southern California, pp. 1586–1588. Amer. Assoc. Petrol. Geol., 1936.

vertebrate or invertebrate paleontologists, at least in that part of the geologic column near the Miocene-Pliocene boundary.

Because of the present state of disagreement with regard to the European section, disagreement in vertebrate correlations based on the genus *Hipparion*, and the clearly recognizable marine-nonmarine stratigraphic relations in the Mint Canyon area, the age determination of the Mint Canyon formation is here based on the invertebrate time scale of California, and the formation is therefore considered to be upper Miocene. This places the beds in a Tertiary marine succession whose record is essentially complete (as opposed to the fragmentary continental record and to the incomplete European marine record) and whose period boundaries commonly correspond to epeirogenic boundaries in the Pacific coast province. *Hipparion* remains thus occur stratigraphically below a Neroly marine fauna, with an appreciable sedimentary break between the two.

An apparent faunal gradation appears within the Mint Canyon formation, as shown by detailed mapping. *Hipparion* is found in the upper two-thirds of the section, and seems to give way to a merychippine fauna in the lowermost strata (see fig. 5). An intermediate protohippine fauna may exist, but disagreement exists concerning the forms. There is an indication, however, that a considerable time range is represented by the deposition, although even the lowermost beds may be post-Barstow in age.

The marine equivalent of the Mint Canyon formation is not found in the Ventura Basin east of the San Gabriel fault, in which area only Neroly marine strata are exposed. West of the fault, in the type section of the Modelo, the Modelo formation (restricted) of Hudson and Craig [35] is probably in part the equivalent of the Mint Canyon (see fig. 7). The unconformity noted by these investigators between the restricted Modelo and deposits which they call Santa Margarita may correspond to the Mint Canyon–"Modelo" unconformity of the Bouquet Canyon–Haskell Canyon area.

GEOLOGIC HISTORY

The geologic history of the Mint Canyon region has been touched upon in the discussion of various aspects of the present study. A brief review, therefore, should suffice to bring all the structural and lithologic data into a coherent sequence. The following events, in chronological order, are postulated for Tertiary and Quaternary time:

1. Early Tertiary (perhaps late Eocene) faulting, with attendant formation of an elongated topographic basin bordered for the most part by igneous terranes.
2. Oligocene and possibly early Miocene deposition of poorly sorted, coarse fanglomerates, sandstones, and silty beds in the basin, which was gradually subsiding.

[35] F. S. Hudson and E. K. Craig, Bull. Amer. Assoc. Petrol. Geol., vol. 13, pp. 509–518, 1929.

3. Extravasation of many flows and shallow intrusions of andesite and basalt during most of the period of accumulation of the thick Vasquez series.
4. Strong early Miocene faulting and subsidiary folding, in many cases along earlier zones of movement, elevating the Vasquez beds to a topographic position sufficiently high to induce active erosion.
5. Late lower Miocene deposition of the Tick Canyon strata, apparently in alluvial fans (fronting the steeper slopes), floodplains, and local lakes, with concomitant volcanism as evidenced by the presence of tuffaceous beds.
6. Early middle Miocene cessation of deposition, accompanied perhaps by uplift and minor folding.
7. Deposition of the Mint Canyon strata, both as coarse fluviatile and as fine lacustrine sediment; volcanism in adjacent areas is demonstrated by several lacustrine tuffaceous beds.
8. Late Miocene uplift and moderate erosion, concurrent with small-scale orogenic movements.
9. Invasion by marine waters from the west and deposition in them of the uppermost Miocene "Modelo" sandstones and shales.
10. Recession of the marine waters, post-"Modelo" folding, and at a slightly later time strike-slip faulting.
11. Pliocene and early Pleistocene development of broad, open plains receiving coarse sediment from adjacent dominantly granitic highlands.
12. Minor folding and warping.
13. Pleistocene terrace formation in much the same manner as in 11 above.
14. Uplift and dissection of terrace deposits.
15. Recent alluviation and minor uplifts.

FAUNA OF THE TICK CANYON FORMATION

Occurrence and Preservation of Material

Fossils are very sparsely distributed in the Tick Canyon strata. Only four localities yielding more than splinters of bone have been reported since collecting first began. Previously described material was obtained from thin fault slices of the Tick Canyon formation near the Mint Canyon narrows, but the material described in the following pages was collected from a large exposure near the head of Vasquez Canyon (*Bt* on the geologic map, fig. 4). The fossiliferous beds are reddish-brown sandy siltstones, occurring about 360 feet stratigraphically below the base of the Mint Canyon formation. Though chalky and very fragile, the remains themselves are well preserved. The occurrence, in which fairly complete skulls, dental series, and limb bones are found, is in striking contrast to that in the younger Mint Canyon strata, where remains are very fragmentary. None of the bones seems to have suffered from abrasion. Apparently the conditions of burial were favorable to the preservation of several individuals within a

small area, for many skeletal parts were found in close association. These features suggest a death from some catastrophe with immediate and rapid burial.

List of Species

The following faunal list comprises the forms definitely recorded from the Tick Canyon formation:

Rodentia:
- Heteromyid, prob. n. gen. and sp.
- Archaeolagus (?) sp.

Perissodactyla:
- Parahippus maxsoni, n. sp.

Artiodactyla:
- Merychyus calaminthus, n. sp.
- Miolabis californicus Maxson

Faunal Environment

Geologic observations furnish evidence of the existence of an adjacent mountain mass to the northwest during Tick Canyon time. The rather rapid progression from conglomeratic strata to fine-grained siltstones and clays further suggests a fairly flat-lying area of deposition at the base of this mountain mass. Certain strata noted in the section signify the presence of lakes; these were not of the playa type, but probably attained considerable depths. It is not surprising that these postulated conditions, which favor not inconsiderable local variations in environment, are in agreement with the evidence presented by the mammalian forms.

The pocket mouse is not particularly diagnostic so far as environment is concerned, in view of the present wide distribution of related forms under varying climatic conditions. The lagomorph, on the other hand, is suggestive, though not necessarily indicative, of a plains environment. *Parahippus*, with its short-crowned grinding teeth, was probably a browsing type, favoring wooded areas rather than an open, grassy terrane. *Merychyus* and *Miolabis* may have been plains-dwellers, although wooded areas near bodies of water probably attracted them. An analysis of the fauna as a whole, when combined with available geologic data, lends support to the view that the environment was that of a broad grassy plain, moderately and perhaps irregularly wooded, with a higher mountain mass lying immediately to the northeast. The climate was probably mild, with a rainfall greater than that which characterizes the region today.

Evolutionary Stage of Fauna

The various mammals of the Tick Canyon fauna present a homogeneous picture so far as stage of advance, as indicated by the phylogenetic development of individual types, is concerned. On the basis of recognized age determinations of North American Tertiary mammal horizons occupying an equivalent position in the evolutionary sequence, the Tick Canyon forms

may be regarded as late lower Miocene or possibly earliest middle Miocene in age. In spite of the prevalence of new species, the fossil material is well enough preserved to afford an evaluation of those characters most necessary for determination of the stage of evolution represented. The rodents indicate a stage presumably rather low in the Miocene. The equid material exhibits characters most commonly found in forms known from the lower Miocene. The well-preserved merycoidodonts resemble most closely Great Plains species from the upper Harrison and upper Rosebud, and the camelid is typically more primitive than allied forms from the middle Miocene.

Faunal Relationships

Comparative lists of mammalian species from the Tick Canyon, lower Hawthorn of Florida, and upper Harrison of Nebraska appear below. The latter two horizons are chosen because they most closely approximate the position of the Tick Canyon fauna in the Tertiary vertebrate sequence (see fig. 7). No direct comparison of the Rodentia is possible, but the Equidae and Merycoidodontidae are closely related. Although the camelid forms listed from horizons occurring beyond the Californian area are of the giraffe-camel line, they nevertheless show evolutionary characters corresponding to those of *Miolabis californicus*.

Comparative faunal lists

Tick Canyon	Lower Hawthorn	Upper Harrison
Rodentia:	Rodentia	Rodentia:
Heteromyid, prob. n. gen. and sp.		Indet. sp.
Archaeolagus (?) sp.		
Perissodactyla:	Perissodactyla:	Perissodactyla:
Parahippus maxsoni, n. sp.	Archeohippus nanus	Parahippus coloradensis praecurrens
	Parahippus leonensis	Parahippus nebrascensis
		Parahippus n. primus
		Parahippus wyomingensis
		Parahippus pawniensis atavus
Artiodactyla:	Artiodactyla:	Artiodactyla:
Merychyus calaminthus, n. sp.		Merycochoerus magnus
		Merychyus arenarum minimus
		Merychyus a. leptorhynchus
Miolabis californicus	Oxydactylus floridanus	Oxydactylus longipes
		Oxydactylus brachyceps
		Procamelus (?) sp.

Pacific coast. The Tick Canyon is the only horizon of the Pacific coast province in which *Parahippus* appears to be the characteristic type of horse. The Merychippus zone at Coalinga [36] and the Caliente horizon,[37] in which *Parahippus* is found, are characterized by several merychippine types. Even the Phillips Ranch horizon,[38] occupying a position in the stratigraphic

[36] F. D. Bode, Carnegie Inst. Wash. Pub. No. 453, paper VI, p. 70, 1935.
[37] J. F. Dougherty, Carnegie Inst. Wash. Pub. No. 514, paper VIII, p. 115, 1940.
[38] J. P. Buwalda, Univ. Calif. Publ., Bull. Dept. Geol., vol. 10, pp. 75–85, 1916.

column slightly in advance of the Tick Canyon, yields a primitive *Merychippus*. The species of *Parahippus* occurring in the Caliente fauna appears to be a much more advanced form than *P. maxsoni*. The Coalinga anchitheriine, *P. brevidens*, exhibits a similar relation. Among the oreodonts, *Merychyus calimontanus* from the Caliente is a larger and more advanced form than *M. calaminthus*.

A large gap appears in the column below the Tick Canyon, the horizons nearest in age being the lower Miocene upper Sespe [39] and the lower Miocene or upper Oligocene Tecuya.[40] The only comparable forms from these horizons are oreodonts of much more primitive character than *M. calaminthus*.

Great Basin. The Tertiary vertebrate horizons of the Great Basin most nearly related to the Tick Canyon are the Virgin Valley,[41] Skull Spring,[42] and Mascall.[43] *Parahippus brevidens* and *P. avus* from the latter are advanced forms, as is *P.* near *coloradensis* from the Skull Spring horizon. This indication of later age is further borne out by the presence of merychippine forms in the Nevada and Oregon faunas. The merycoidodonts in these assemblages are generically distinct and thus preclude direct comparison, but they exhibit characters generally considered to be more advanced than those of the Tick Canyon form. The only camelid comparable to *Miolabis californicus* is *M. transmontanus* from the Mascall, a species whose characters are distinctly more advanced than those of the former. When comparisons are made with the upper John Day, the great faunal disparity is demonstrated by the presence in that formation of *Mesohippus*, *Eporeodon*, and *Paratylopus*, types that are much more primitive than comparable forms known from the California horizon.

Great Plains. The similarity of the upper Harrison faunas [44] to that from Tick Canyon, as based on the comparisons of *Parahippus*, *Merychyus*, and the long-limbed camels, has been noted. *Merychyus delicatus* from the upper Rosebud [45] most closely approaches *M. calaminthus* from the Tick Canyon; the equid and camelid forms from these two horizons likewise show similarities. The Sheep Creek horizon [46] presents a fauna slightly more advanced, but forms comparable to those from Tick Canyon are present. *Parahippus cognatus*, *Merychyus* sp., and *Miolabis tenuis* are larger and more advanced than *P. maxsoni*, *M. calaminthus*, and *M. californicus*, respectively. Presence in the fauna of *Merychippus insignis primus* is also indicative of a later stage. The lower Rosebud horizon is earlier in the

[39] C. Stock, Carnegie Inst. Wash. Pub. No. 404, paper III, pp. 31–36, 1930.

[40] C. Stock, Univ. Calif. Publ., Bull. Dept. Geol., vol. 12, pp. 267–276, 1920; Carnegie Inst. Wash. Pub. No. 418, paper IV, p. 89, 1932.

[41] J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, pp. 204–209, 1911.

[42] C. L. Gazin, Carnegie Inst. Wash. Pub. No. 418, paper III, pp. 42–48, 1932.

[43] J. C. Merriam and W. J. Sinclair, Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, pp. 195–197, 1907.

[44] O. A. Peterson, Ann. Carnegie Mus., vol. 4, pp. 56–72, 1906.

[45] F. B. Loomis, Bull. Amer. Mus. Nat. Hist., vol. 51, pp. 31, 33–34, 1924.

[46] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 65–73, 1924.

FIG. 7. Correlation chart showing time relations of middle Tertiary invertebrate and vertebrate horizons. Note position of the Mint Canyon and Tick Canyon faunas.

Miocene, so much so that it has been correlated with the upper Sespe.[47] The lower Harrison is also earlier, but apparently does not range quite so far down in the lower Miocene as does the lower Rosebud.

Atlantic-Gulf coast. The only mammal-bearing horizons in this province comparable to the Tick Canyon are the upper and lower Hawthorn of Florida.[48] That the lower Hawthorn is closely related to the California horizon, in spite of a paucity of comparable forms, has been pointed out. The upper Hawthorn differs from the Tick Canyon in yielding a primitive *Merychippus*, but lacks the presence of other forms on which a correlation might be established; it may be considered as approximately of same age as the Phillips Ranch horizon of the Pacific coast province.

Correlation. The upper lower Miocene position of the Tick Canyon formation, approximately equivalent to that of the upper Rosebud, upper Harrison, and lower Hawthorn, as well as its suggested marine analogues, is indicated in figure 7. Certain revisions in the section dealing with vertebrate horizons suggested by recent work in the Caliente Mountains have been the result of discussions with J. F. Dougherty. The section on California stratal units is taken from Kleinpell [49] and the division of the Modelo formation is the work of Hudson and Craig.[50] The following lists of certain Tertiary perissodactyls and artiodactyls are furnished for purposes of comparison not only with the Tick Canyon, but with the overlying Mint Canyon, thus demonstrating the faunal gap between the two.

DESCRIPTION OF SPECIES

Rodentia

Dr. Robert W. Wilson, who contemplates a detailed study of the Tick Canyon rodents and lagomorphs, has kindly supplied the following preliminary statement concerning the several forms involved:

The small mammal specimens obtained from quarry 201 comprise two incomplete skulls and five rami of a heteromyid rodent possibly representing a new genus, and two maxillae and three rami of a lagomorph, *Archaeolagus* (?).

The heteromyid genus has a premolar pattern typical of the perognathine division of the family, and except for the absence of grooves in the upper incisors is comparable superficially to the genus *Perognathus*. Characters in addition to the smooth incisors which may be noted are: (1) $P\underline{4}$ with single-cusped protoloph; union with metaloph delayed but median or slightly lingual; (2) palate between premolars slightly ridged; (3) $P\overline{4}$ relatively small, four-cusped; metalophid and protolophid well separated but uniting to form X pattern (protolophid joins metalophid via anteroexternal cusp); (4) weak H pattern in lower molars; some development of Y-shaped anterior crest but stylid not anterior in position; (5) cusps of cheek teeth apparently

[47] C. Stock, Carnegie Inst. Wash. Pub. No. 404, paper III, pp. 31–34, 1930.

[48] G. G. Simpson, Florida Geol. Surv., Bull. 10, pp. 11–16, 1932.

[49] R. M. Kleinpell, Miocene stratigraphy of California, fig. 14. Amer. Assoc. Petrol. Geol., 1938.

[50] F. J. Hudson and E. K. Craig, Bull. Amer. Assoc. Petrol. Geol., vol. 13, pp. 509–578, 1929.

Comparative perissodactyl-artiodactyl faunal lists of certain North American Tertiary horizons

1. Ricardo
2. Mint Canyon
3. Barstow
4. Lower Snake Creek
5. Coalinga
6. Skull Spring
7. Mascall
8. Caliente
9. Sheep Creek
10. Upper Hawthorn
11. Lower Hawthorn
12. Tick Canyon
13. Upper Rosebud
14. Upper Harrison
15. Upper John Day

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Perissodactyla:															
Pliohippus-Hipparion forms	×	×													
Protohippus-Merychippus forms		×	×												
Archeohippus mourningi			×		×										
Archeohippus ultimus							×								
Archeohippus penultimus									×						
Archeohippus cf. nanus										×					
Archeohippus nanus											×				
Merychippus (Protohippus) intermontanus		× ?	×												
Merychippus calamarius stylodontus			×												
Merychippus sumani		× ?	×												
Merychippus paniensis				×											
Merychippus proparvulus				×											
Merychippus campestris				×											
Merychippus eohipparion				×											
Merychippus sejunctus				×											
Merychippus brevidontus					×										
Merychippus californicus					×										
Merychippus isonesus						×	×								
Merychippus stevensi								×							
Merychippus seversus							×								
Merychippus relictus							×								
Merychippus insignis							×								
Merychippus carrizoensis								×							
Merychippus insignis primus									×						
Merychippus gunteri										×					

(*Continued on following page*)

Comparative perissodactyl-artiodactyl faunal lists of certain North American Tertiary horizons—Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Perissodactyla—*continued*															
Parahippus integer				×											
Parahippus brevidens					×		×								
Parahippus near coloradensis						×									
Parahippus avus							×								
Parahippus sp.								× ?							
Parahippus cognatus									×						
Parahippus leonensis											×				
Parahippus maxsoni, n. sp.												×			
Parahippus coloradensis praecurrens													×	×	
Parahippus nebrascensis														×	
Parahippus nebrascensis primus														×	
Parahippus wyomingensis														×	
Parahippus pawniensis atavus														×	
Mesohippus equiceps															×
Mesohippus acutidens															×
Mesohippus praestans															×
Artiodactyla:															
Metoreodon californicus	×														
Metoreodon relictus				×											
Merycochoerus buwaldi			×												
Merycochoerus sp.							×								
Merycochoerus magnus														×	
Merycochoerus matthewi													×		
Merycoidodont sp.							×	×		×					
Ticholeptus sp.						×		× ?							
Pronomotherium siouense				×					×						
Merychyus sp.				×					×						
Merychyus calimontanus								×							
Merychyus calaminthus, n. sp.												×			
Merychyus delicatus													×		
Merychyus arenarum minimus														×	
Merychyus arenarum leptorhynchus														×	

Comparative perissodactyl-artiodactyl faunal lists of certain North American Tertiary horizons—Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Artiodactyla—*continued*															
Eporeodon sp.															×
Eporeodon major longifrons															×
Promerycochoerus, several sp.															×
Alticamelus sp.		×	×		× ?										
Alticamelus leptocolon				×											
Alticamelus procerus				×											
Alticamelus altus							×								
Alticamelus priscus									×						
Oxydactylus sp.					× ?										
Oxydactylus floridanus											×				
Oxydactylus longipes													×	×	
Oxydactylus brachyceps														×	
Pliauchenia sp.			×												
Procamelus sp.			×		×								× ?		
Protolabis angustidens				×					×						
Protolabis pusillus									×						
Protolabis saxeus									×						
Miolabis sp.					× ?					× ?			×		
Miolabis fissidens				×											
Miolabis transmontanus							×								
Miolabis tenuis									×						
Miolabis californicus												×			
Paratylopus cameloides															×

remain prominent for some time; (6) traces of posterior cingula in lower cheek teeth, anterior cingula in upper cheek teeth in some, at least, of the specimens; (7) $M\frac{3}{3}$ not noticeably reduced; (8) height of crowns moderate. The Mint Canyon heteromyid possesses an assemblage of characters which makes it difficult to allocate to any of the established genera. Structurally, it might be ancestral to either *Perognathoides* or *Cupidinimus*. Perhaps it is closer to the latter. No definite age determination can be made on the basis of the material at present, but a Miocene rather than Pliocene age is indicated.

The lagomorph remains apparently represent an advanced *Archaeolagus* or a very primitive *Hypolagus*. The Mint Canyon genus has a $P\underline{2}$ with only one anterior inflection. $P\overline{3}$ is very close to the comparable tooth in *Archaeolagus*. The upper molars have simple, short inflections without crenulations. These teeth lack the enamel crescents present, though not invariably, in the John Day *Archaeolagus*. Anterior and posterior columns of $M\overline{3}$ are united by an isthmus of dentine of varying width, and none of the three specimens available exhibits the complete separation of the columns typical of *Hypolagus*. Cited characters indicate a form close to *Archaeolagus*, which in turn suggests a rather early Miocene age, but probably post-John Day, for the specimens. However, notes by L. R. Dice [51] on *Panolax* Cope indicate that forms of *Archaeolagus* type may have existed as late as the Santa Fe.

Perissodactyla

Parahippus maxsoni, n. sp.

(Plate 1, figure 1)

Holotype. C.I.T. No. 1385, palate of immature individual with well-preserved deciduous grinding teeth, a cervical vertebra, part of a humerus, shaft of fibula and tibia, incomplete manus and right pes.

Type locality. C.I.T. Vert. Pale. Loc. 201; west side of small canyon in the SW. corner of section 25, T. 5 N., R. 15 W., San Bernardino Base and Meridian, Humphreys Quadrangle, U. S. Geological Survey.

Geologic horizon. Tick Canyon formation, upper part of lower Miocene or lowermost middle Miocene.

Specific characters. Comparisons based on individual deciduous tooth measurements, as well as on the length of the deciduous premolar series, indicate a size greater than that of *Parahippus pristinus*,[52] but less than that of *P. cognatus* Leidy,[53] the genotype, and *Merychippus isonesus* (Cope).[54] The teeth are short-crowned, with a rather primitive pattern involving simple, straight, connected lophs, strongly developed cingulum below protoloph, and short, well-developed triangular hypostyle. A tiny crochet appears on the metaloph of $Dp\underline{3}$ and $Dp\underline{4}$. Cement is lacking, or present in negligible amount. The dentition resembles that of *P. pristinus*, but differs specifically in greater size, and in development of crochet, greater prominence of parastyle and mesostyle, and greater elongation of $Dp\underline{2}$. The

[51] L. R. Dice, Jour. Mammal., vol. 4, no. 3, 1923.

[52] H. F. Osborn, Mem. Amer. Mus. Nat. Hist., vol. 2, pt. 1, pp. 76–77, pl. 25.1, 1918.

[53] Joseph Leidy, Proc. Acad. Nat. Sci. Phila., vol. 10, p. 26, 1858; Jour. Acad. Nat. Sci. Phila., vol. 7, p. 314, 1869.

[54] F. D. Bode, Carnegie Inst. Wash. Pub. No. 453, paper V, pl. 2, 1934.

metapodials and phalanges suggest an animal of rather light build. The pes is anisotridactylous.

The writer takes pleasure in naming this species for Dr. John H. Maxson.

Description

Dentition. The teeth are represented by a well-preserved set of deciduous cheek teeth. The narrowness of the space separating the right and left series may be due to a considerable crushing of the palate. The milk teeth are short-crowned, little worn, and very closely spaced. The length of the series, 61.6 mm., is compared with that of other forms in the table of measurements. The peglike first premolar is relatively large, elongated anteroposteriorly. Its crown is divided into two distinct basins, the posterior of which is much the smaller, roughly ovoid in shape, and shallow when compared with the crown height of the tooth. The large anterior basin is bounded externally by a strong, crescentic ridge, interiorly by a very low, narrow ridge. This tooth seems to have functioned, at least in part. The second premolar is the longest tooth present; it is markedly narrower than in *P. pristinus*, broader than in *M. isonesus*, but of nearly the same proportions as in *P. cognatus*. Although the transverse dimension of the remaining teeth increases to a maximum in Dp4, these teeth are relatively less broad than in most other species of the genus. The enamel surfaces are smooth, but local areas of slight rugosity do occur, chiefly on the interior faces of the lophs, on which appear tiny, irregular vertical striations. Local patches of a very thin calcareous scale, confined in general to the outer face of the ectoloph and to the inner surfaces of protocone and hypocone, may represent cement. The total amount present is very small. When the tooth row is viewed from the side, it presents a gently downward convex profile.

The protoloph, though sharply constricted and slightly bent between protocone and protoconule, is simple, continuous, and fairly straight. The bulbous, subconical protocone is larger than the protoconule, which is developed as a ridge-shaped swelling on the loph. The metaloph crest drops to a low saddle and follows a single tiny plication before joining the ectoloph. This union becomes progressively stronger from Dp2 to Dp4. The hypocone is symmetrically formed; from a point near its apex the metaloph slopes away in a nearly straight, continuous ridge, on which a metaconule is faintly indicated. An extremely small, thin, and bladelike crochet projects from the anterior side of the metaloph in Dp3 and Dp4, perhaps also in Dp2. This feature appears in the occlusal pattern only after much wear. Ptychoid crenulations and additional crochets are absent. The short hypostyle is strongly developed and triangular in cross section. It nearly encloses a small fossette, but opens externally in a sharp, V-shaped groove. By means of a low, narrow ridge it connects with the ectoloph, the most elevated part of the tooth. No pli-hypostyle is present.

A strong cingulum lies at the base of the protoloph; additional cingula are represented internally by the merest traces at the anterointernal base of the hypocone, externally by a slightly better defined bench at the base of the ectoloph. The external walls of the paracone and metacone are smooth, broken only by a low, narrow, rounded median rib. The para- and mesostyles are prominent, though rounded and narrow. A bladelike metastyle is distinct on Dp3 and Dp4, whereas on Dp2 the protostyle reaches prominence.

In its broad aspects the deciduous tooth pattern of the Tick Canyon specimen agrees with that of *Miohippus gemmarosae* Osborn,[55] an advanced form of the genus from the lower Rosebud formation, but differs in the union of metaloph and ectoloph, in the presence of a crochet, and in the shape of the individual teeth. Although the same differences in pattern persist, there is closer agreement in tooth shape and size with a species described by Douglass [56] as *Altippus taxus* and by Osborn [57] as *Parahippus taxus*, but later referred to the genus *Miohippus* by Schlaikjer.[58] From the dentition of *P. pristinus*, *P. maxsoni* differs in its larger size, presence of two basins in Dp1, superior development of the crochet, greater prominence of para- and mesostyles, and greater elongation of Dp2. Comparisons with the occlusal pattern of permanent dentitions furnish little of specific value, but lengths of premolar series are included in the table of measurements. In this respect, *P. maxsoni* is larger than *P. pristinus*, roughly comparable to *P. coloradensis praecurrens*, *P. pawniensis*, and *P. avus*, and distinctly smaller than *P. nebrascensis*, *P. nebrascensis primus*, *P. crenidens*, *P. tyleri*, and *P. wyomingensis*.

FIG. 8. *Parahippus maxsoni*, n. sp. Skeletal parts of feet, C.I.T. No. 1385, front view; ×½. Lower Miocene, Tick Canyon Formation, California.

Skeleton. The vertebral column is represented by one partially preserved third or fourth cervical. Although the neural spine is broken off, the specimen seems to have been of rather small size. The transverse process is wide and stubby. The zygapophyses are large, the prezygapophyses having a marked forward extent. The ventral keel is sharp and prominent. The neural canal is ovoid in section, with a moderate amount of flattening. The vertebrarterial canal is large and round.

The fore-limb bones are very fragmentary. The distal portion of a humerus bears a deep, elongated olecranon fossa, strongly developed epicondyle, and lateral condyloid crest. The only carpal bone present is a magnum, typically more flattened than in *Miohippus*. On the ventral surface are a strong, flat face and a small oblique facet for articulation with the third and second metacarpals, respectively. Articulating faces for scaphoid and lunar are represented by slight concavities on the dorsal surface,

[55] H. F. Osborn, *op. cit.*, pp. 66–68, 1918.
[56] E. Douglass, Ann. Carnegie Mus., vol. 4, pp. 271–273, 1908.
[57] H. F. Osborn, *op. cit.*, pp. 85–86, 1918.
[58] E. M. Schlaikjer, Bull. Mus. Comp. Zool., Harvard, vol. 80, p. 272, 1937.

from the rear of which rises a strong projection. The phalanges are in general like those of the hind foot, but are shorter and broader.

Portions of shafts of fibula and tibia denote a slender build; both are nearly circular in section throughout their middle extent, with a diametral ratio of approximately 1 : 4.5. A gently curving cnemial crest becomes very strong near the proximal end of the tibia. The only bone of the tarsus preserved is a cuboid. This element is large and extended anteroposteriorly. Although its proximal surface is transversely convex, it differs from that in *P. wyomingensis* in lacking an anteroposterior concavity on the rear portion. Additional articulating surfaces located on the distal side are an ovoid facet for metatarsal IV and a small oblique facet for metatarsal III; on the internal side, a faintly concave ovoid facet for the navicular. A large, bulbous tuberosity is present on the posterointernal corner of the distal surface. Remains of feet are shown in figure 8. Metapodial III is long and slender, with an expanded distal portion. A shallow, transversely elongated fossa lies on the dorsal surface of the distal portion, midway between the lateral tubercles. Both the rounded articulating surface and its keel are canted backward. The distal ends of metapodials II and IV show similar relations, but are much smaller and compressed transversely. The ungual phalanx is strongly notched at its distal end.

Discussion

Although the skeletal characters, so far as they are known, serve only to indicate an appreciable advance over *Miohippus*, the dentition of *P. maxsoni* is far more diagnostic. Comparisons with other deciduous dentitions seem to fix within reasonably small limits the stage of evolution of this species in the genus. That the Tick Canyon species represents a more advanced stage than does the lower Miocene *P. pristinus* and a slightly earlier stage than does the middle Miocene *P. cognatus* has been pointed out. The negligible amount of cement, very simple loph structure, and shape and size of the teeth denote rather primitive characters, even for a deciduous dentition. Inasmuch as both milk and permanent dentitions are known for *P. pristinus*, if we accept Schlaikjer's suggestion [59] that *P. cognatus* and *P. coloradensis praecurrens* (the latter represented by permanent teeth) are specifically identical, the opportunity presents itself to compare *P. maxsoni* with other members of the genus, at least so far as relative evolutionary development is concerned. It appears that the Californian species occupies a position in the evolutionary sequence of the Equidae corresponding to that of forms from the upper Harrison and upper Rosebud formations of the Great Plains province, or to that of the Merycochoerus-Parahippus zone of Osborn.[60] Further, it seems reasonable to refer to *P. maxsoni* the equid material previously collected from the same beds. This specimen was described by Maxson [61] as *Parahippus ?* (*Archeohippus*) near *mourningi* and later referred by Bode [62] and Stirton [63] to *Parahippus* sp. Bode notes at least one character which suggests that this fossil species belonged to an earlier stage than that to which it has been assigned (upper Miocene).

[59] *Ibid.*, pp. 275–276, 1937.
[60] H. F. Osborn, *op. cit.*, p. 79, 1918.
[61] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, pp. 91-92, 1930.
[62] F. D. Bode, Carnegie Inst. Wash. Pub. No. 440, paper V, pp. 55–56, 1933.
[63] R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 26, pp. 570–571, 1933.

*Comparative measurements (in millimeters) of deciduous dentitions**

1. *Parahippus maxsoni*, n. sp., C.I.T. No. 1385.
2. *Parahippus pristinus* Osborn, A.M. No. 12915.†
3. *Parahippus cognatus* Leidy, U.S.N.M. No. 567.‡
4. *Parahippus taxus* Douglass, Car. Mus. No. 836.† §
5. *Merychippus isonesus* (Cope), C.I.T. No. 544.‖

	1	2	3	4	5
Superior series, Dp1 to Dp4, length	61.6	54	..	59¶	..
Superior series, Dp2 to Dp4, length	55.5	46	67¶	50¶	65
Dp1, anteroposterior diameter	9.2	11	..	11	..
Dp1, transverse diameter	6.5	6	..	7	..
Dp1, crown height	8.1	**	..	**	..
Dp2, anteroposterior diameter	21.2	17	25	20¶	27
Dp2, transverse diameter	15.0	14	18	15	18
Dp2, crown height	11.1	**	..	**	11
Dp3, anteroposterior diameter	17.0	14	19	15	20
Dp3, transverse diameter	16.8	15	20	16	19
Dp3, crown height	12.5	**	..	**	13
Dp4, anteroposterior diameter	18.5	15	20	15	20
Dp4, transverse diameter	17.8	15	20	17	19
Dp4, crown height	13.6	**	..	**	12

* Anteroposterior diameter of Dp1 and Dp2 is the maximum diameter at the base of crown; otherwise the system of measurements is that of Bode (*op. cit.*, p. 46, 1933).
† H. F. Osborn, *op. cit.*, pp. 76–77, 85–86, 1918.
‡ Joseph Leidy, *op. cit.*, p. 314, pl. 21, 1869.
§ Referred to genus *Miohippus* by Schlaikjer.
‖ F. D. Bode, *op. cit.*, pl. 2, 1934.
¶ Approximate.
** Measurements not taken because of worn character of tooth.

*Comparison of permanent dentition of Parahippus maxsoni with those of other forms (measurements in millimeters)**

Species	Superior premolar series, P1 to P4	Superior premolar series, P2 to P4
Parahippus maxsoni (C.I.T. No. 1385)	61.6†	55.5†
Parahippus pristinus Osborn (A.M. No. 12918)	50	42
Parahippus tyleri Loomis (Amer. Coll. No. 1079)	65‡	59
Parahippus nebrascensis Peterson (Car. Mus. No. 1440)	72	66
Parahippus n. primus Osborn (A.M. No. 13770)	77	71
Parahippus coloradensis praecurrens Osborn (A.M. No. 13018)	..	54
Parahippus avus Marsh (Yale Mus. No. 11281)	61‡	57
Parahippus crenidens Scott (Prin. Mus. No. 10430)	68	58
Parahippus pawniensis Gidley (A.M. No. 9085)	59	51
Miohippus gemmarosae Osborn (A.M. No. 13808)	61	52
Parahippus wyomingensis Schlaikjer (M.C.Z. No. 6309)	65	59

* Measurements taken in part from Osborn.
† Deciduous dentition.
‡ Approximate.

Limb measurements (in millimeters)

	Parahippus maxsoni	*Parahippus wyomingensis* Schlaikjer*
Metatarsal III, maximum length	154.6	223.4
Metatarsal III, maximum width at proximal end	20.0†	30.2
Metatarsal III, maximum width at distal end	20.4	30.0
First phalanx of middle digit, pes, maximum length	30.4	42.8
Second phalanx of middle digit, manus, maximum length	20.7	28.1
Second phalanx of middle digit, pes, maximum length	25.0	29.7
Ungual phalanx, manus, middle digit, maximum length	23.1	34.8
Ungual phalanx, manus, middle digit, maximum width	21.3	....
Ungual phalanx, pes, middle digit, maximum length	24.6	40.7
Ungual phalanx, pes, middle digit, maximum width	20.0†	35.5

* E. M. Schlaikjer, *op. cit.*, pp. 270–271, 1937.
† Approximate.

*Measurements (in millimeters) and indices of the ungual phalanx, middle digit, of the pes**

Species	Length	Width	Index
Parahippus pristinus	26.0	19.0	0.730
Parahippus pawniensis atavus	33.0	26.0	.790
Parahippus maxsoni	24.6	20.0†	.81†
Parahippus avus	35.5	30.0	.845
Parahippus leonensis	28.0	24.0	.856
Parahippus tyleri	39.0	33.5	.859
Parahippus wyomingensis	40.7	35.5	.872
Parahippus coloradensis praecurrens	35.0	31.0	0.886

* Data on all species other than *P. maxsoni* taken from Schlaikjer.
† Approximate.

Artiodactyla

Merychyus calaminthus, n. sp.

(Plate 1, figures 2–3*a*; plates 2, 3)

Cotypes. C.I.T. No. 1383, incomplete skull of an adult animal with nearly perfect cheek-tooth series; C.I.T. No. 1342, poorly preserved adult mandible; C.I.T. No. 1382, middle and posterior part of skull with nearly complete molar series and well-preserved basicranial region; C.I.T. No. 1829, skull of an immature animal, complete anterior to cranium, lower jaws present, one in articulation with skull and one separated.

Paratypes. C.I.T. No. 1384, imperfect skull and lower jaws of a young individual; C.I.T. No. 2684, miscellaneous teeth; C.I.T. No. 2681, parts of left hind foot and tibia.

Type locality. C.I.T. Loc. 201; west side of small canyon in SW. corner of section 25, T. 5 N., R. 15 W., San Bernardino Base and Meridian, Humphreys Quadrangle, U. S. Geological Survey.

Geologic horizon. Tick Canyon formation, upper part of lower Miocene or lowermost middle Miocene.

Specific characters. The most mature specimens are slightly smaller than *Merychyus delicatus*, heretofore the smallest recorded species of the genus,[64] and notably smaller than *M. arenarum minimus*[65] and *M. curtus*.[66] The slender build is further indicated by the small eye socket, slender zygomata, and smallness of cranial region of the skull. The most diagnostic single character, however, is a pronounced ovoid antorbital fossa, at the anterior edge of which is a tiny facial vacuity. The dentition closely resembles that of *M. delicatus*, with uncrowded premolars and characteristic premolar pattern; the only notable character is a distinct spur projecting outward from the inner crescent of $P\underline{4}$.

Description

Skull. Although no complete skull is available, accurate composite measurements indicate a mesocephalic index of about 0.54. The dorsal surface, as shown in No. 1382, is low and flattened, with its highest point at the postorbital constriction. The brain case has a nearly circular horizontal cross section, and its upper surface is marked by two broad, very low temporal ridges. These ridges unite just in back of the glenoid fossae to form a short, narrow sagittal crest that is clearly defined but not prominent. The occipital crests are sharp and well developed.

[64] F. B. Loomis, Bull. Amer. Mus. Nat. Hist., vol. 51, art. 1, pp. 31, 33–34, fig. 22, 1924.
[65] O. A. Peterson, Ann. Carnegie Mus., vol. 4, pp. 56, 67–68, fig. 16, 1906.
[66] F. B. Loomis, *op. cit.*, pp. 31–33, figs. 19, 20, 1924.

The malar is of medium build, but the zygomatic arches are light. The elevated orbits are rather small and only slightly elongated anteroposteriorly. From the orbits, the lachrymals project forward to occupy a rather extensive area on the face; they are concave outward, forming pronounced, anteroposteriorly elongated antorbital fossae. At the front edges of these ovoid depressions are very small facial vacuities, bounded mainly by the maxillaries, in part by the lachrymals, and apparently to a small extent by the frontals. The short nasals are widest at their anterior ends. These elements appear to be slightly constricted at the middle, and are rounded posteriorly. The frontals, flat to gently convex, rise to a low ridge at the orbital rim. Although the relations are obscured to some extent by dorsoventral crushing, the palate appears to be gently vaulted and wide.

Both basioccipital and basisphenoid are narrow and strongly convex downward. The tympanic bullae are not preserved. Projection of the occiput over the foramen magnum is not great. The pterygoids are not fully preserved, but appear to have been thin; the vomer, on the other hand, is thick. The rather open glenoid fossae lie in a line normal to the basicranial axis, and are bounded posteriorly by sharply defined, downward-directed postglenoid processes. Although the paroccipital processes are broken off, they seem to have been sensibly smaller than the postglenoid processes.

Mandible. The inclination of the symphyseal border of the jaw makes an angle of 43° with the tooth row in the young individual, No. 1384; this angle is apparently increased in more mature animals. The symphysis is short and vertically slightly convex. The inferior edge of the mandible is straight, sloping gently backward and terminating in a poorly defined angle; the depth of the jaw at this point is considerably less than in other representatives of the genus. The coronoid process is short, thin, and rounded at its end. A broad and shallow sigmoid notch is bounded posteriorly by a slender condyle with very straight transverse surface. At its horizontal, clearly marked lower edge, the masseteric fossa is deep, but becomes shallower toward the coronoid process.

Foramina. In spite of local crushing, several foramina are clearly visible in the basicranial region. A large foramen ovale is situated internally with respect to the glenoid fossa, and a small, round foramen lacerum anterius is completely concealed in ventral view by a marked overhang of the pterygoid. There is no trace of a foramen rotundum, and an alisphenoid canal is not present; instead, the carotid artery appears to have been carried in a short, moderately narrow, but very deep groove. This groove is bounded exteriorly by a stubby pyramidal process situated on the posterior outer edge of the alisphenoid, and interiorly by one of the ventrally diverging pterygoids.

A portion of the rim of the foramen lacerum medium is preserved posterointernally to the foramen ovale, and there is a suggestion of an edge of a foramen lacerum posterius in back of the space occupied by the tympanic bulla.

The infraorbital foramina lie above the middle part of $P\underline{3}$, and the posterior palatine foramina occupy positions opposite $P\underline{4}$. The supraorbital foramina are only 5 mm. apart, and are situated immediately adjacent to the frontonasal suture. They open into shallow grooves which apparently extend directly forward. The mental foramen, the only one observable in the mandible, lies below the anterior end of $P\overline{3}$.

Dentition. The superior teeth are sub-hypsodont to hypsodont, and are closely spaced but not crowded. The incisors are small, with ovoid cross sections; the canines are pyramidal and moderately large. The molar-premolar rows are nearly straight both horizontally and vertically, although a tendency toward downward convexity is displayed in immature individuals. Except for a backward tilt in P1 and P2 and an oblique position for P1, the individual cheek teeth stand straight in the jaw. The molars, which overlap slightly, increase in length rapidly from M1 to M3. M2 resembles M1 more closely in size than it does M3. M1 is essentially square in outline, in which character this tooth differs from the posterior molars. This difference is due in part to differential wear. Shortening of the tooth row has taken place with reduction in size of the anterior parts of P1, P2, and P3 and with complete loss of the anterior end of P4.

The cheek teeth follow the typical *Merychyus* pattern, with the addition of certain minor characters. A small but distinct spur projects outward from the inner crescent of P4, but lies too far posterior to be a vestige of the median crest. The tiny pit (a remnant of the anterior basin) present at the anterior outer corner of P4 in *M. curtus* and *M. delicatus* is absent in *M. calaminthus*. Below the corners of the crescent are short cinguli; the anterior one is very sharp and trough-like. No distinct cingulum is present elsewhere in teeth of the upper dentition. In P3, which is shorter transversely than in *M. delicatus*, the posterior basin is obliquely elongated. The anteriorly convex anterior intermediate crest is sharper and more prominent than either of the adjacent crests or the anterior crescents. This crest has a greater extent in P2, and in the latter tooth that portion of the basin in front of the intermediate crest is vestigial or absent. Parastyle and mesostyle are inconspicuous in M1, but become increasingly prominent in M2 and M3. Moreover, M3 possesses a distinct metastyle.

FIG. 9. *Merychyus calaminthus*, n. sp. Left pes with tibia, inner view; ×1. *As*, astragalus; *Na*, navicular; *En*, entocuneiform; *Ec* & *Me*, ecto- and mesocuneiform; II, III, V, metatarsals. Lower Miocene, Tick Canyon Formation, California.

The superior milk dentition is represented by poorly preserved premolars. The molariform Dp4 seems crowded into a nearly square outline; it contains two basins and bears a well-developed parastyle, mesostyle, and metastyle.

$Dp\underline{2}$ and $Dp\underline{3}$ are too imperfectly preserved to permit a clear picture of their occlusal patterns.

Because of the worn grinding surfaces of the inferior teeth, little of their pattern can be discerned. The premolars are crowded and partially overlapping, $P\bar{1}$ and $P\bar{2}$ lying transversely in the jaw. The strongly caniniform $P\bar{1}$, though short-rooted, is larger than the canine, which is also transverse. As in the superior dentition, $M\bar{3}$ is much larger than $M\bar{1}$ or $M\bar{2}$. Styles are strongly developed, especially on the molars. Straight, narrow internal cinguli appear on $P\bar{3}$ and $P\bar{4}$, which are further characterized by a very deep indentation of the external wall just forward of the posterior crest, with an attendant anterior narrowing of each tooth. The deciduous lower teeth show much the same characters as the corresponding permanent units, except for the molariform, three-basined $Dp\bar{4}$, whose well-defined crescents are separated by deep, narrow valleys extending only part way down the crown. Styles typical of the molars are also present on this tooth.

Skeleton. Among the best preserved of the skeletal remains is a left pes, with the distal parts of the tibia and a thin, slender fibula; all bones are in articulation (fig. 9). The phalanges are missing, and of the metatarsals only the second is reasonably complete. The estimated length from the end of metatarsal II to the posterior end of the calcaneum is 81 mm. The cuboid is rather elongated; the navicular shows a slender anterior projection on the under side of the foot; and the middle and external cuneiform bones are not fused. That the animal was of light build is indicated by the relative slenderness of all the foot bones, especially the metatarsals (for comparisons with *M. arenarum minimus*, see table of measurements). Other, more fragmentary and poorly preserved hind-limb elements have similar characteristics.

Discussion

Although the brain case is slightly wider than in *M. delicatus*, the smaller features of *M. calaminthus* are reflected by lighter zygomata, more restricted skull width between orbits, and smaller diameter of orbit. The skull in the Californian species is of nearly the same shape as in *M. arenarum minimus*, as is shown by comparison of cephalic indices, 0.54 and 0.55 respectively; that of *M. delicatus* is 0.62 (approximately). Differences in the dentition are seen in the molar-premolar ratios, 0.80 for *M. calaminthus* as compared with 0.83 for *Merycoidodon*, 0.84 for *Merychyus delicatus*, and 0.74 for *M. arenarum minimus*. In addition to the differences in occlusal pattern of the premolars that have been pointed out, it should be noted that complete internal cinguli, present in $P\underline{4}$ and $M\underline{3}$ of *M. delicatus*, are absent in the comparable teeth of the species from southern California.

Merychyus calaminthus is more primitive than most species of the genus, as is demonstrated by its cephalic index, small size, restricted facial vacuities, presence of an open groove which appears to represent a vestigial alisphenoid canal, lack of extensive shortening in $P\underline{2}$ and $P\underline{3}$, lack of strong backward cant to upper premolars, and the heavy styles in $M\underline{3}$. On the other hand, this form may represent a slight advance beyond *M. delicatus*, as is indicated perhaps by presence of a facial vacuity, slightly broader brain case, lower molar-premolar index (reflecting greater premolar shortening), and more complex premolar pattern. Additional comparisons can be made from the table of measurements.

Comparative measurements (in millimeters)

1. *Merychyus calaminthus*, n. sp., C.I.T. No. 1383.
2. *Merychyus calaminthus*, n. sp., C.I.T. No. 1342.
3. *Merychyus calaminthus*, n. sp., C.I.T. No. 1382.
4. *Merychyus calaminthus*, n. sp., C.I.T. No. 1829.
5. *Merychyus calaminthus*, n. sp., C.I.T. No. 1384.
6. *Merychyus delicatus* Loomis.*
7. *Merychyus arenarum minimus* Peterson.*
8. *Merychyus curtus* Loomis.*

Skull	1	3	4	5	6	7	8
Maximum length	.....	.....	126.0†	96.0‡	140‡	160.0	156
Basal length	.....	.....	.....	.....	130‡	148.0	148
Bizygomatic diameter	75.0‡	67.9	68.0	.....	88‡	88.5‡	98
Postorbital constriction, diameter	.....	36.0	35.0	33.0‡	34	34.5	32
Brain case, diameter	.....	42.3	42.0‡	36.0‡	40‡	44.0	42
Width between middle of orbits	58.0	50.0	48.5	42.0‡	56	58.0	50
Orbits, anteroposterior diameter	21.5	20.0	18.8	.....	24	22.0	25
Orbits, vertical diameter	20.0	16.2	14.7	.....	20	24.0	24
Molar, depth below orbit	13.0	10.8	8.0	.....	12	16.0	18
Bulla, anteroposterior diameter	.....	.....	.....	.....	16	19.6	22
Bulla, transverse diameter	.....	.....	.....	.....	.....	14.0	18
Palate, width between P1	20.5‡	.....	16.5	12.8‡	.....	19.6	21
Palate, width between M3	25.0‡	23.0	22.0	16.5‡	.....	24.6	28
Facial vacuity, maximum diameter	.....	.....	3.0‡	.....	.....	19.0	14
Facial vacuity, minimum diameter	.....	.....	.....	.....	.....	10.0	3
Ramus, maximum length	.....	.....	82.0‡	91.0‡	110	129.0	122
Symphyseal length	.....	.....	.....	20.0	27	32.0	25
Depth, coronoid to angle	.....	.....	50.0‡	.....	71	73.0	76
Depth below M3	.....	.....	20.0	.....	28	28.0	27
Cephalic index	.....	.....	0.54	.....	0.62‡	0.55	0.62

* Measurements taken in part from M. R. Thorpe, Mem. Peabody Mus. Nat. Hist., vol. 3, 1937.
† Composite value; measurements made on two specimens.
‡ Approximate.

Superior dentition	1	3	4	5	6	7	8
Superior dental series, C to M3	.....	.....	.....	.....	74.0	77.0	70.0
Superior molar series	36.2	31.0	28.6	30.0‡	36.0	40.5	38.0
Superior premolar series	29.0	.....	.....	.....	30.2	30.0	28.0
C, anteroposterior diameter	.....	.....	5.4	3.4	4.0	7.3	4.0
C, transverse diameter	.....	.....	4.4	2.5	4.0	6.7	6.0
P1, anteroposterior diameter	6.9	.....	6.0	6.5	7.3	7.1	6.3
P1, transverse diameter	4.5	.....	4.4	3.7	5.6	4.3	4.5
P2, anteroposterior diameter	7.7	.....	.....	.....	9.0	9.4	7.5
P2, transverse diameter	6.5	.....	.....	.....	7.5	7.0	5.8
P3, anteroposterior diameter	8.1	.....	.....	.....	8.0	9.2	7.5
P3, transverse diameter	7.8	.....	.....	.....	9.0	8.6	7.2
P4, anteroposterior diameter	7.3	.....	.....	.....	7.7	8.6	7.0
P4, transverse diameter	9.2	.....	.....	.....	10.9	10.4	9.0
M1, anteroposterior diameter	10.7	8.6	10.2	8.7	9.7	12.3	12.0
M1, transverse diameter	10.8	8.7	9.3	7.3	12.6	12.5	11.5
M2, anteroposterior diameter	13.5	11.7	13.5	9.5	12.5	15.2	14.0
M2, transverse diameter	11.9	11.5	10.8	8.7	14.1	14.1	13.0
M3, anteroposterior diameter	15.7	14.2	13.9‡	12.0‡	16.4	18.6	15.0
M3, transverse diameter	13.0	10.5	10.6	8.5‡	15.1	14.7	12.0
Molar-premolar index	0.80	.....	0.80	.....	0.84	0.74	0.74

‡ Approximate.

(*Continued on following page*)

Comparative measurements (in millimeters)—continued

Inferior dentition	2	4	5	6	7	8
Inferior molar series	36.0‡	.....	.....	39.0	43.0	42.0
Inferior premolar series	.....	.....	.....	29.0	30.0	33.0
$\overline{C}$, anteroposterior diameter	.....	.....	4.0	.....	4.5	2.0
$\overline{C}$, transverse diameter	.....	.....	3.1	.....	6.5	.....
$P\overline{1}$, anteroposterior diameter	4.3	6.6	4.7	.....	8.0	5.0
$P\overline{1}$, transverse diameter	4.7	5.2	2.5	.....	6.3	4.0
$P\overline{2}$, anteroposterior diameter	.....	.....	6.2	8.0	8.3	6.0
$P\overline{2}$, transverse diameter	.....	.....	3.0	4.0	5.3	3.0
$P\overline{3}$, anteroposterior diameter	7.2	.....	8.1	9.0	9.5	9.8
$P\overline{3}$, transverse diameter	5.3	.....	4.1	6.6	5.3	4.0
$P\overline{4}$, anteroposterior diameter	9.0	.....	.....	10.2	11.6	10.5
$P\overline{4}$, transverse diameter	6.0	.....	.....	8.0	7.0	5.2
$M\overline{1}$, anteroposterior diameter	8.4	9.5	10.4	10.1	10.7	9.7
$M\overline{1}$, transverse diameter	7.1	6.7	6.0	8.9	8.9	6.2
$M\overline{2}$, anteroposterior diameter	10.3	13.0	12.7‡	12.0	14.2	11.5
$M\overline{2}$, transverse diameter	7.3	7.5	7.5	10.2	9.5	6.5
$M\overline{3}$, anteroposterior diameter	17.4	12.0‡	.....	20.0	21.7	19.0
$M\overline{3}$, transverse diameter	8.2	7.0‡	.....	10.3	10.7	7.5

‡ Approximate.

Deciduous dentition	4	5
Superior deciduous series, length	23.0	....
$Dp\overline{2}$, anteroposterior diameter	6.2	....
$Dp\overline{2}$, transverse diameter	4.9	....
$Dp\overline{3}$, anteroposterior diameter	7.4	....
$Dp\overline{3}$, transverse diameter	7.1	....
$Dp\overline{4}$, anteroposterior diameter	7.8	....
$Dp\overline{4}$, transverse diameter	8.2	6.1
Inferior deciduous series, length	24.0	26.5
$Dp\overline{2}$, anteroposterior diameter	5.0	....
$Dp\overline{2}$, transverse diameter	3.6	....
$Dp\overline{3}$, anteroposterior diameter	6.9	....
$Dp\overline{3}$, transverse diameter	4.1	....
$Dp\overline{4}$, anteroposterior diameter	11.6	12.5
$Dp\overline{4}$, transverse diameter	5.8	5.4

Skeleton	C.I.T. No. 2681	*M. a. minimus*§
Length of left pes, calcaneum to distal end of metatarsal II	81.0 ‡	83.0
Calcaneum, length	34.8	35
Calcaneum, average depth	10	....
Calcaneum, average transverse diameter	7	....
Navicular, maximum depth	12.7	....
Astragalus, transverse diameter at distal pulley	11.6	12.2‡
Metatarsal II, length	41.0‡	42.0‡
Metatarsal II, dorsoventral diameter of shaft	3.8	....
Metatarsal II, transverse diameter of shaft	4.6	3.0
Metatarsal III, dorsoventral diameter of shaft	5.5‡	....
Metatarsal III, transverse diameter of shaft	6.5	7.0
Metatarsal IV, dorsoventral diameter of shaft	5.0‡	....
Metatarsal IV, transverse diameter of shaft	6.0‡	7.0
Metatarsal V, dorsoventral diameter of shaft	3.9	....
Metatarsal V, transverse diameter of shaft	3.7	4.0

‡ Approximate.
§ O. A. Peterson, Ann. Carnegie Mus., vol. 15, pp. 299–304, 1923.

Camelidae

(?) **Miolabis californicus** Maxson

Two lower teeth, C.I.T. Nos. 2682 and 2683, were obtained at C.I.T. Loc. 201. They represent a moderately worn fourth premolar and an unworn deciduous premolar of like position. Although the absence of a lower dentition in the type specimen precludes the possibility of direct comparison, these teeth are provisionally referred to *Miolabis californicus* Maxson.[67]

The size of the specimens presumably agrees with that of *M. californicus* as inferred from the upper dentition of the latter. $P\bar{4}$ is larger than in *Miolabis tenuis* Matthew [68] and roughly comparable to the corresponding tooth in *Oxydactylus floridanus* Simpson,[69] *O. longipes* Peterson,[70] and *Paratylopus cameloides* (Wortman).[71] Lack of mandibular material prevents comparison with *Miolabis transmontanus* (Cope), the genotype. Though typically compressed laterally, the tooth is broader, longer-crowned, and more robust than in *Paratylopus cameloides*. It has two roots, the posterior of which is strongly developed on the inner side. In spite of its fore-and-aft straightness, an asymmetrical appearance is caused by a marked constriction throughout the whole of the anterior portion.

The curvature of the posterior crescent is concentrated at the tooth corner, resulting in a straight posterior edge and a broad, slightly convex inner wall. The posterior valley appears only near the base of the crown. The most unusual character is the anterior narrowing of the tooth. This causes a compression of the crescent and creates a broadly concave inner wall, thus thrusting the anterior pit backward against the median crest. The external valley so well developed in *P. cameloides* and in *O. floridanus* is absent in the Tick Canyon specimen, its place being taken by the internal constriction noted above. The posterior pit is large and pear-shaped, and is situated centrally within the basin, as contrasted with its extreme posterior position in *P. cameloides*.

The narrow, sharp mesostylid is exceeded in prominence by a strong parastylid, hooklike in section. A corresponding prong on the interior corner is slightly less developed than the parastylid. Broad, low median ribs, extending downward from the posterior and anterior crests, mark the outer surface. No cinguli are present.

The deciduous tooth is a typical three-lobed fourth premolar, with very strong constrictions between the lobes. In shape it is not unlike the corresponding tooth in *Procamelus coartatus* Stirton,[72] although it is smaller in size.

Discussion

The teeth are referred to *M. californicus* not only because they were collected in the same stratigraphic horizon as the type, but because they have characters suggesting a comparable stage of evolution among the Camelidae. Although no mandibular material is available in the type specimen, the size, shape, and robust build of the permanent fourth premolar indicate rather primitive features characteristic of the skull described by Maxson.

[67] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, pp. 106–109, 1930.
[68] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 191–193, 1924.
[69] G. G. Simpson, Florida Geol. Surv. Bull. 10, pp. 35–37, 1932.
[70] O. A. Peterson, Ann. Carnegie Mus., vol. 2, p. 446, 1904.
[71] J. L. Wortman, Bull. Amer. Mus. Nat. Hist., vol. 10, pp. 117–120, 1898.
[72] P. C. Henshaw, Carnegie Inst. Wash. Pub. No. 514, paper I, pp. 21–22, 1939.

It seems worthy of note that certain questions pertaining to the ancestry of *M. californicus* are clarified by the new information on the age of the strata in which it occurs. An age determination as upper lower Miocene rather than upper Miocene, as based on diagnostic equid and oreodont material, furnishes the explanation for the anomalous situation noted by Maxson,[73] wherein the Tick Canyon camel appeared to be more closely related to John Day and White River types than to *M. tenuis* and *M. longiceps* from the Sheep Creek beds of Nebraska. Moreover, *M. californicus*, which seems to have more primitive features than *M. transmontanus*, occurs in beds now known to be older than Mascall, from which the genotype is recorded. A late lower Miocene age thus satisfies fully all the conflicting stratigraphic and biologic evidence.

Comparative measurements (in millimeters)

1. (?) *Miolabis californicus* Maxson, C.I.T. No. 2682.
2. *Miolabis tenuis* Matthew, A.M. No. 18965.*
3. *Paratylopus cameloides* (Wortman), C.I.T. No. 128.
4. *Oxydactylus floridanus* Simpson, F.S.G.S. No. V-5238.†
5. *Oxydactylus longipes* Peterson, Car. Mus. No. 918.‡
6. *Procamelus coartatus* Stirton, C.I.T. No. 2316.§

	1	2	3	4	5	6
$P\bar{4}$, anteroposterior diameter	13.0	9‖	11.4	13.5	12	11.2
$P\bar{4}$, transverse diameter	6.7	6‖	5.3	7.5	7	5.5

	M. californicus (C.I.T. No. 2683)	*P. coartatus* (C.I.T. No. 2319)
$Dp\bar{4}$, anteroposterior diameter	19.2	25.5
$Dp\bar{4}$, transverse diameter, anterior lobe	5.1	5.7
$Dp\bar{4}$, transverse diameter, middle lobe	5.8	7.2
$Dp\bar{4}$, transverse diameter, posterior lobe	6.1	6.8

* W. D. Matthew, *op. cit.*, pp. 191–193, 1924.
† G. G. Simpson, *op. cit.*, p. 37, 1932.
‡ O. A. Peterson, *op. cit.*, p. 446, 1904.
§ P. C. Henshaw, *op. cit.*, p. 22, 1939.
‖ Approximate.

[73] J. H. Maxson, *op. cit.*, p. 108, 1930.

PLATE 1

Parahippus maxsoni, n. sp.

FIG. 1. Type specimen, No. 1385, palate, with deciduous dentition, $Dp\underline{1}$–$Dp\underline{4}$, occlusal view. × 1.

Merychyus calaminthus, n. sp.

FIGS. 2, 2*a*. Imperfect mandible with lower dentition, No. 1384. Fig. 2, lateral view; fig. 2*a*, occlusal view. × 1.

FIGS. 3, 3*a*. Mandible and lower dentition, No. 1829. Fig. 3, lateral view; fig. 3*a*, occlusal view. × 1.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Miocene, Tick Canyon, California.

1

2a

2

3a

3

1

1a

2

2a

PLATE 2

Merychyus calaminthus, n. sp.

FIGS. 1, 1*a*. Cotype, incomplete skull and upper dentition, No. 1382. Fig. 1, lateral view; fig. 1*a*, occlusal view. × 1.

FIGS. 2, 2*a*. Cotype, middle and posterior part of skull, No. 1382. Fig. 2, dorsal view; fig. 2*a*, ventral view. × 1.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Miocene, Tick Canyon, California.

PLATE 3

Merychyus calaminthus, n. sp.

FIGS. 1, 1*a*. Cotype, skull and lower jaw, No. 1829. Fig. 1, anteroexternal view; fig. 1*a*, dorsal view. × 1.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Miocene, Tick Canyon, California.

1a

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