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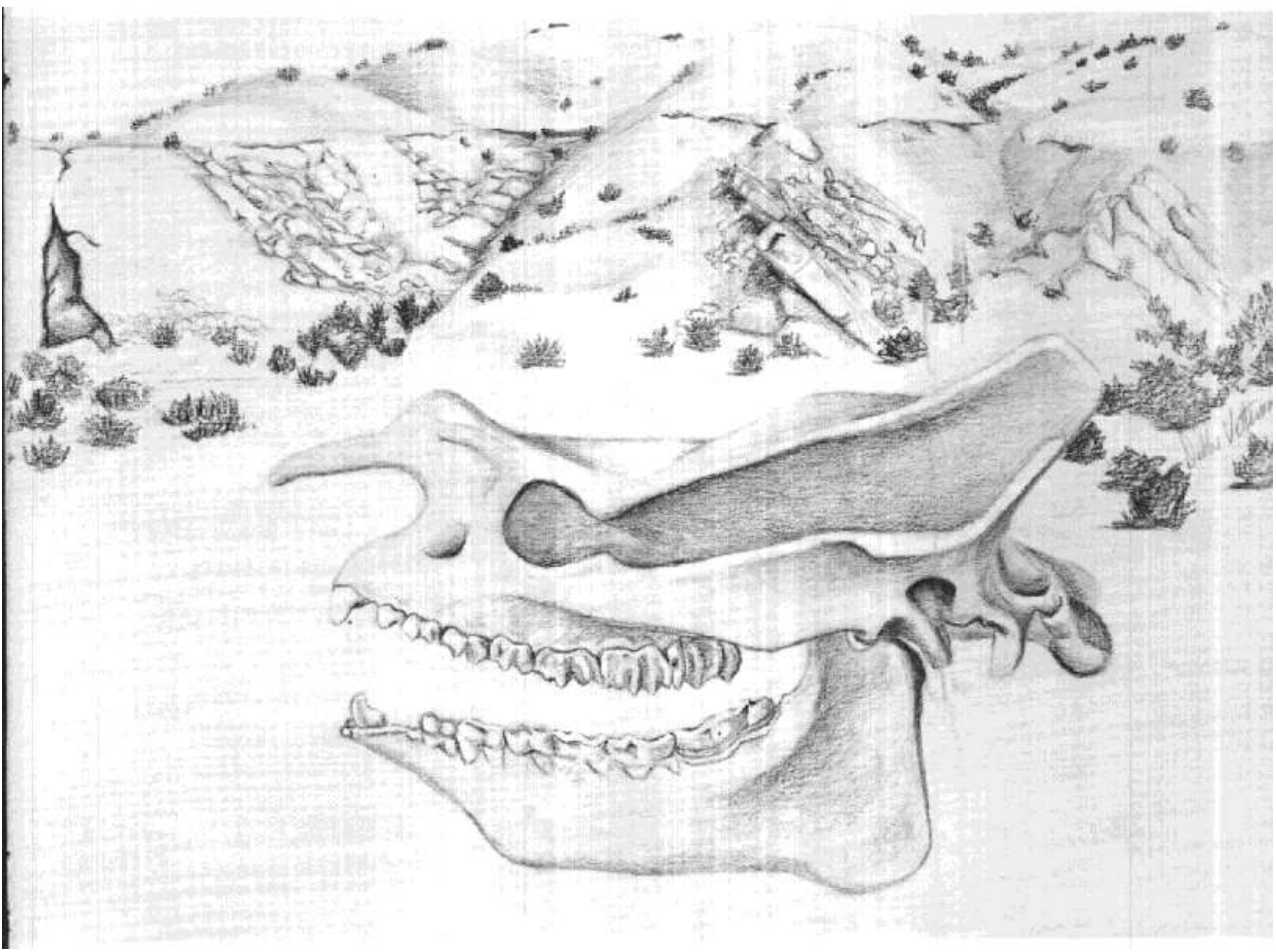
by Spencer G. Lucas



New Mexico Bureau of Mines & Mineral Resources

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COVER—ARTIST'S RENDERING OF SKULL OF *TELEODUS* (from Scott, 1945) superimposed on drawing of Galisteo Formation outcrops cast of Cerrillos unconformably overlain by Ancha Formation.

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Preface

The purposes of this study were to: 1) describe and identify the vertebrate fossils known from the Galisteo Formation, 2) place these vertebrates in their precise stratigraphic context in the Galisteo Formation, 3) use vertebrate fossils and rock-stratigraphy to correlate major outcrops of the Galisteo Formation with each other, and 4) determine the age of the Galisteo Formation and correlate it with other formations both in and outside of New Mexico. In accomplishing these purposes, I hope to provide a precise chronologic framework for the Galisteo Formation that will aid further in deciphering the early Tertiary history of north-central New Mexico.

Abbreviations used in text

AMNH—Department of Vertebrate Paleontology, American Museum of Natural History, New York
CM—Carnegie Museum of Natural History, Pittsburgh
d—deciduous tooth
F:AM—Frick Collection, American Museum of Natural History, New York
LACM—Los Angeles County Museum of Natural History, Los Angeles
L—length: maximum antero-posterior length of a tooth
MCZ—Museum of Comparative Zoology, Harvard University, Cambridge
NMC—National Museum of Canada, Ottawa
PU—Department of Geology, Princeton University, Princeton
SDSM—Museum of Geology, South Dakota School of Mines and Technology, Rapid City
UCM—University of Colorado Museum, Boulder
UCMP—University of California Museum of Paleontology, Berkeley
UNM—Department of Geology, University of New Mexico, Albuquerque
W—width: maximum transverse width of a tooth. AW is the maximum anterior (trigonid) width of a tooth; PW is the maximum posterior (talonid) width of a tooth.
YPM—Peabody Museum of Natural History, Yale University, New Haven

Descriptive terminology for sandstones and mudrocks follows Folk (1974). Terminology for titanothere teeth follows Osborn (1929); terminology for the teeth of other fossil mammals follows Szalay (1969).

ACKNOWLEDGMENTS—For invaluable assistance in the field I thank S. Cobb, J. W. Froehlich, W. Gavin, T. Gorham, B. S. Kues, M. B. Leaf, T. Lehman, F. M. O'Neill, P. Reser, M. Somerville, C. Tsentas, and S. Wing. For permission to collect from Galisteo outcrops under their jurisdiction, I thank R. Peterson, 0. E. Shelton, the owners of the Diamond Tail Ranch, and the Albuquerque District Office of the U.S. Bureau of Land Management. For permission to study specimens under their care, I thank R. Tedford and M. C. McKenna (AMNH), C. Schaff (MCZ), P. Robinson (UCM), D. Savage (UCMP), B. S. Kues (UNM), and J. Ostrom (YPM). For informative discussions on Galisteo collecting, specimens, and the problem of the Duchesnean land-mammal "age," I thank R. Emry, T. Gorham, E. Manning, M. C. McKenna, P. Robinson, R. Tedford, and C. B. Wood. R. Schoch and W. Kohlberger provided photographic assistance. M. B. Leaf typed the manuscript. National Science Foundation Grant DEB-7919681 supported part of this research.

New Haven, Connecticut
June 4,1981

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Contents

Tables

Figures

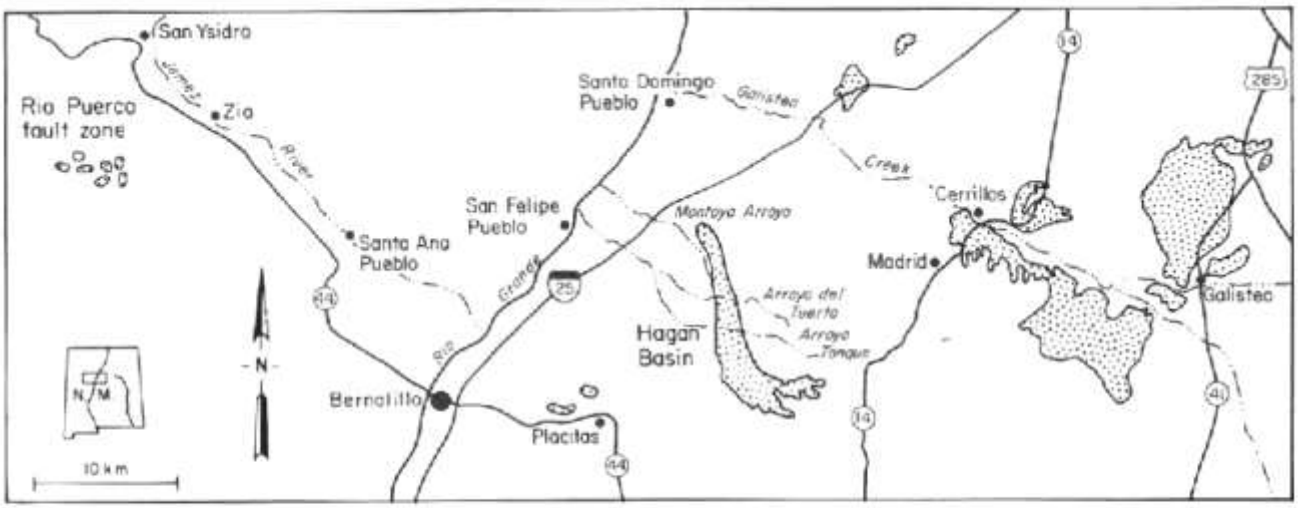

FIGURE 1—MAJOR OUTCROPS OF GALISTEO FORMATION (stippled) in north-central New Mexico (modified from Gorham and Ingersoll, 1979).

Abstract

The Galisteo Formation consists of up to 1,300 m (4,300 ft) of fluvial sandstone, mudstone, siltstone, claystone, and conglomerate deposited during the early Tertiary in a basin in north-central New Mexico. Fossil vertebrates are found in the Galisteo Formation in four areas: east of Cerrillos along the north and south banks of the Galisteo Creek, the headlands of Montoya Arroyo in the Hagan Basin, the headlands of Arroyo del Tuerto in the Hagan Basin, and the Windmill Hill area in the Rio Puerco fault zone. Outcrops of the Galisteo Formation east of Cerrillos in secs. 14, 15, 16, 21, 22, and 23, T. 14 N., R. 8 E. are the type area of the formation as first recognized by Hayden (1869). An 1,100-m-(3,600-ft)-thick measured section of the Galisteo Formation in this area is designated the type section of the formation. Wasatchian (early Eocene) fossil vertebrates of the Cerrillos local fauna are found in red mudstones 369-424 m (1,210-1,391 ft) above the base of the Galisteo Formation in this section. The Cerrillos local fauna includes gars, trionychid turtles, and the mammals *Ectoganus* sp., *Microsyops* sp., *Coryphodon* sp., Paramyidae, *Hyopsodus powellianus*, cf. *Homogalax protapirinus*, and *Hyracotherium* sp. Fossil mammals of the Duchesnean (late Eocene) Tongue local fauna are found in the upper 231 m (758 ft) of the type section and also are found in approximately equivalent strata in Montoya Arroyo, Arroyo del Tuerto, and the Windmill Hill area. The Tonque local fauna includes trionychid and non-trionychid turtles and the mammals *Pterodon* sp., *Teleodus* cf. *T. uintensis*, Brontotheriidae, *Forstercooperia minute*, *A mynodon* sp., *Protoreodon* sp., *Poabromylus* cf. *P. minor*, and Protoceratidae. The Duchesnean is recognized as a valid land-mammal "age" whose limits are defined by immigration events. It is characterized by the Lapoint fauna of the Duchesne River Formation in Utah and its correlatives, the Pearson Ranch local fauna of the Sespe Formation, California, and the Porvenir local fauna of the Chambers Tuff, Texas. The upper yellow pebbly sandstone member of Gorham (1979) and Gorham and Ingersoll (1979) is used to lithologically correlate Galisteo outcrops in the Windmill Hill area, Hagan Basin, and Cerrillos area. This lithologic correlation is supported biostratigraphically by the distribution of the Tongue local fauna. The Galisteo Formation (Wasatchian-Duchesnean) is a time equivalent in part of the San Jose Formation (Wasatchian) in northwest New Mexico and the Baca Formation (Bridgerian-Duchesnean) in south- and west-central New Mexico.

Introduction

The early Tertiary history of the Rio Grande rift in New Mexico presents a challenging problem to geologists. Prior to the initiation of the rifting, fluvial deposition took place in several sedimentary basins in central New Mexico. The resultant deposits of sandstone, siltstone, mudstone, and conglomerate were faulted and deformed by the rifting and, in some places, were buried under hundreds of meters of upper Tertiary sedimentary deposits and igneous rocks. The **lower Tertiary** sediments include the El Rito, Galisteo, and Baca Formations and are now generally exposed as isolated and structurally complex outcrops. Precise age and stratigraphic relationships are not fully understood.

Because these formations are mostly fluvial in origin, age relationships depend largely upon fossils of terrestrial plants and animals. Until recently few fossils have been reported from the Galisteo and Baca Formations, and no fossils have ever been reported from the El Rito Formation. However, the present study resulted in an extensive collection of vertebrate fossils from the Galisteo Formation in and around the northern Albuquerque Basin (fig. 1) to determine more precisely the age, correlation, and stratigraphic relationships of these rocks.

Previous studies

The famous Santa Fe trader Josiah Gregg (1844, p. 114) made the "earliest definite reference to fossils in (New Mexico)" (Northrop, 1962, p. 33) when he mentioned "arboreous petrifactions in the vicinity of Galisteo, still standing erect." Subsequent explorers and geologists also mentioned petrified wood in the Galisteo Creek valley (for example, Abert, 1848; Wislizenus, 1848; LeConte, 1868; Newberry, 1876) and suggested it was from rocks of Triassic age.

Hayden (1869, p. 166-167) first named the "variegated sands and sandstones" along the Galisteo Creek east of Cerrillos the "Gallisteo (sic) sand group." Hayden believed that these rocks were Tertiary in age, although the only fossils he found were "enormous silicified trunks of trees."

After Hayden, some confusion arose over what strata constituted the "Galisteo sand group" that naturally resulted in general disagreement over its age (for example, Loew, 1875; Cope, 1875a, b; Stevenson, 1875, 1879; Herrick, 1898b). Johnson (1902-03) reviewed these studies and concluded that the "Galisteo Sand Group" consisted of "fifteen hundred feet or more of

. . . red sandstones" (p. 67) and probably was Cretaceous in age. Johnson (1902-03) believed the Galisteo was present only in the valley of the Galisteo Creek (fig. 2). Other outcrops now assigned to the Galisteo Formation then, and for many years after, were mapped as "Red Beds" (Herrick, 1898a; Herrick and Johnson, 1900), "Fort Union Beds" (Reagan, 1903), "Wasatch Formation" (Renick, 1931), "Cretaceous" (Bryan and McCann, 1937) or as part of the "Gibson Coal Member of the Mancos Formation" (Hunt, 1936).

Lee and Knowlton (1917, p. 207-210, pl. 29c) first attempted to extend the distribution of the Galisteo beyond its type area by assigning strata near Madrid now assigned to the Mesaverde Group to the Galisteo. They also briefly described strata of the Galisteo Formation in the Rio Puerco fault zone and Hagan Basin, but did not assign them to the Galisteo Formation. Lee and Knowlton (1917) recognized an unconformity at the base of the Galisteo Formation, separating it from the underlying coal-bearing strata of Cretaceous age. They also reported the first identified plant fossils from the Galisteo: *Sabal? ungeri* and *Dryopteris?* sp. (Lee and Knowlton, 1917, p. 212). Based on these fossils, the stratigraphic position of the Galisteo and its lithology, Lee and Knowlton (1917, p. 185) concluded that "the Galisteo sandstone should be correlated with Tertiary formations farther west."

After Lee and Knowlton, the petrified wood in the Galisteo Formation near Cerrillos continued to attract attention (Northrop and Popejoy, 1931; Harrington, 1939; Woods, 1947), but scientific study of the formation virtually ceased until Stearns (1943) wrote what probably is the single most important paper on the Galisteo. In this paper Stearns mapped the Galisteo Formation in the Hagan Basin-Cerrillos area; first recognized the Espinaso Volcanics, the formation that overlies the Galisteo in much of this area; stratigraphically correlated major outcrops of the Galisteo Formation with each other; gave a list of fossil plant taxa from the Galisteo Formation; and reported the first vertebrate fossils from the formation. On the basis of these fossils, he assigned a Duchesnean (late Eocene, though Stearns called it early Oligocene) age to the upper part of the Galisteo. With minor variations, Stearns' (1943) concept of the Galisteo Formation has been utilized by all subsequent workers.

Geological fieldwork in north-central New Mexico after Stearns (1943) resulted in a better understanding of the stratigraphy and distribution of the Galisteo Formation (Harrison, 1949; Stearns, 1953a, b; Disbrow and Stoll, 1957; Sun and Baldwin, 1958; Spiegel, 1961; Spiegel and Baldwin, 1963; Galusha, 1966; Smith and others, 1970). At the same time, sporadic collecting of vertebrate fossils by T. Galusha (AMNH), P. Robinson (UCM), D. Savage and W. Langston (UCMP), and C. B. Wood (MCZ) added to the vertebrate fauna known from the Galisteo. Robinson (1957) reported a *Coryphodon* tooth from the lower part of the Galisteo near Cerrillos, establishing a Wasatchian (early Eocene) age for this part of the formation. However, other than this work, virtually nothing was published on the vertebrate fossils from the Galisteo Formation.

In recent years continued interest in the Rio Grande rift has produced additional information on the Galisteo. Slack (1973, 1975), Black and Hiss (1974), Slack and Campbell (1976), and Kelley (1977) described outcrops of the Galisteo Formation in the Rio Puerco fault zone near San Ysidro but assigned them to the San Jose Formation. Leopold and MacGintie (1972) reported palynomorphs from these same Galisteo outcrops. Kelley and Northrop (1975, p. 162-167) recently provided a brief review of the Galisteo Formation. Gorham (1979) and Gorham and Ingersoll (1979) studied the sedimentology and provenance of the Galisteo Formation in the Hagan Basin. Recent vertebrate paleontological and stratigraphic work on the Galisteo that is more fully documented in this paper has been published by Lucas and Kues (1979) and Lucas (1980, 1981, 1982).

Stratigraphy

Four major Galisteo outcrops have produced fossil vertebrates: east of Cerrillos on the north and south banks of the Galisteo Creek, the headlands of Arroyo del Tuerto in the Hagan Basin, the headlands of Montoya Arroyo in the Hagan Basin, and the Windmill Hill area in the Rio Puerco fault zone *(fig.* I and table 1). Other Galisteo outcrops are not discussed here; they have already been well described by Stearns (1943), Harrison (1949), Sun and Baldwin (1958), Spiegel and Baldwin (1963), and Gorham (1979). In this discussion, I closely follow Stearns' (1943) definition of the Galisteo Formation. Gorham (1979) and Gorham and Ingersoll (1979) mapped seven informal members of the Galisteo Formation in the Hagan Basin. Outside of the Hagan Basin, I have only been able to recognize their "upper yellow pebbly sandstone member" with certainty and use that name informally here. Lucas and Kues (1979) recognized two local faunas in the Galisteo Formation: the Cerrillos local fauna of early Eocene vertebrates from the lower part of the Galisteo and the Tongue

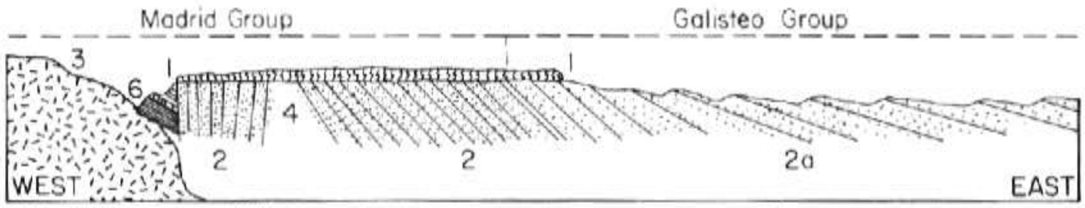

FIGURE 2—JOHNSON'S (1902-03, FIG. 4) CROSS SECTION OF STRATA EXPOSED EAST OF CERRILLOS ALONG NORTH BANK OF GALISTEO CREEK. **1,** Santa Fe; **2,** sandstones; **2a,** red sands of Galisteo Group; **3,** intrusive andesite (laccolith); **4,** concealed; and **6,** carbonaceous shales.

TABLE 1—Synopsis of fossil-vertebrate localities in the Galisteo Formation. Localities with less precise provenance are listed in appendix 2.

Locality	Coordinates	Stratigraphic position
Cerrillos local fauna:		
C1	SE¼SE¼ sec. 16, T.14 N., R.8 E.	fig. 4: unit 37
C2	SE¼SE¼ sec. 16, T.14 N., R.8 E.	fig. 4: unit 38
C3	SE¼SE¼ sec. 16, T.14 N., R.8 E.	fig. 4: unit 41
Tonque local fauna:		
C6	SE¼SE¼ sec. 22, T.14 N., R.8 E.	fig. 4: unit 82
C8	SE¼NW¼ sec. 35,* T.14 N., R.8 E.	fig. 4: unit 82
T1	NW¼NW¼ sec. 4, T.13 N., R.6 E.	fig. 7: unit 1
T2	NE¼SW¼ sec. 4, T.13 N., R.6 E.	fig. 7: unit 1
T3	SW¼NW¼ sec. 4, T.13 N., R.6 E.	fig. 7: unit 2
T4	NE¼SW¼ sec. 4, T.13 N., R.6 E.	fig. 7: unit 3
W1	NE¼SW¼ sec. 2, T.14 N., R.1 E.	fig. 10: unit 9
W2	NE¼SE¼ sec. 2, T.14 N., R.1 E.	fig. 10: unit 10
W3	SE¼NW¼ sec. 11, T.14 N., R.1 E.	fig. 10: unit 18
W4	SW¼NW¼ sec. 11, T.14 N., R.1 E.	fig. 10: unit 18
W5	SW¼NW¼ sec. 11, T.14 N., R.1 E.	fig. 10: unit 21
W6	NE¼SW¼ sec. 11, T.14 N., R.1 E.	fig. 10: unit 21
Montoya Arroyo (M1)	NW¼NE¼ sec. 19, T.14 N., R.6 E.	= unit 1, fig. 7
No local fauna named:		
C4	NE¼NE¼ sec. 21, T.14 N., R.8 E.	fig. 4: unit 56
C5	NE¼SE¼ sec. 15, T.14 N., R.8 E.	fig. 4: unit 74

*section unsurveyed

local fauna of late Eocene vertebrates from the upper part of the Galisteo. These local fauna names are used here and their stratigraphic ranges and composition are more fully documented.

Cerrillos area

Hayden's (1869, p. 166-167) original description of the Galisteo Formation indicates that the type area of the formation almost certainly is in secs. 14, 15, 16, 21, 22, and 23, T. 14 N., R. 8 E. just east of Cerrillos:

> As we descend the hill into the valley of the Gallisteo (sic) Creek, we have a wonderful exhibition of the variegated sands and sandstones, which at first appear like the upper series of red beds on the east side of the mountains, but which I at once suspected were new to me in this region. Descending the Galistco, to the west or lower end of the Cerrillos, we find the full series of the Cretaceous beds (Mancos Shale and underlying units). . . . The Cretaceous beds incline thirty degrees to fifty degrees. Inclining at a less (sic) angle, a series of coal strata (Mesaverde Group) reveal their upturned edges, conforming perfectly to the Cretaceous beds. Passing up the Gallisteo (sic) eastward, we observed the variegated sands and sandstones (Galisteo Formation), rising above the coal strata, and concealing them on the northeast and east flanks of the Placiere Mountain (Mount Chalchihuitl), inclining at all angles from five degrees to fifty degrees. These sandstones are of a varied texture, from a fine aggregate of quartz particles to a rather coarse pudding-stone. . . . 1 have named these beds the Gallisteo (sic) sand group. . . . they pass under the Santa Fe marls, and the northern limit is concealed from view.

I thus consider a 1,100-m (3,600-ft)-thick measured section of the total thickness of the Galisteo Formation east of Cerrillos the type section of the formation (figs. 3, 4). Lucas (1981) briefly described this structurally complex section, and it can be considered in three parts:

1) Lower sandstones—My placement of the Mesaverde Group-Galisteo Formation contact in the Cerrillos area concurs with the placement of Stearns (1943) and Disbrow and Stoll (1957). Stearns (1943) and Gorham (1979) discussed difficulties in determining the position of the Mesaverde-Galisteo contact. The Cerrillos section well exemplifies such difficulties because the Mesaverde-Galisteo contact here is between two sandstones (fig. 4, units 9-10). Mesaverde sandstones below the contact are fine to medium grained and thinly laminated. In contrast, Galisteo sandstones above the contact are coarse grained to conglomeratic and more thickly laminated. Most Mesaverde mudstones are gray and black (organic rich). Most mudstones of the Galisteo Formation, however, are green and red. Although the Mesaverde-Galisteo contact locally appears to be conformable, regionally the contact is a major unconformity representing much of the Late Cretaceous and probably some of the early Tertiary (Stearns, 1943; Gorham, 1979; Beaumont, 1979).

The lower 353 m (1,158 ft) of the Galisteo Formation in the Cerrillos section (fig. 4, units 10-34) are mostly medium- to coarse-grained and conglomeratic, arkosic sandstones (fig. 5A). Other than some poorly preserved petrified wood (fig. 4, unit 26), no fossils have been recovered from these strata. Most of these sandstones were assigned by Johnson (1902-03) to his "Madrid Group" (fig. 2), but subsequent workers have assigned them to the Galisteo Formation (Stearns, 1943; Disbrow and Stoll, 1957).

2) Medial mudstones, sandstones, and conglomerates—Brick-red mudstones, interbedded coarse-grained sandstones, and a few beds of conglomerate represent the medial 561 m (1,840 ft) of the Galisteo Formation in the Cerrillos section (fig. 4, units 35-76). Three fossil localities of the Cerrillos local fauna (figs. 3, 4, 5B; CI, C2, C3) occur in an interval 369-424 (1,210-1,391 ft) above the base of the Galisteo. Robinson (1957, p. 757) collected a tooth of *Coryphodon* "approximately 700 feet above the base of the (Galisteo) Formation east of the Cerrillos" (appendix 2, locality C7). Although relocating the exact horizon that produced this tooth is impossible, its description as a "red mudstone" (Robinson, 1957, p. 757) suggests that it actually is a horizon well over 213 m (700 ft) above the base of the Galisteo; probably the horizon is roughly equivalent to the red mudstone horizons that contain localities C1 and C3. Lucas and Kues (1979) accepted Robinson's (1957) estimate and placed the Mcsaverde-Galisteo contact higher in the Cerrillos section than I do here. They thus placed their Cerrillos local fauna in an interval 183-244 m (600-800 ft) above the base of the Galisteo Formation (Lucas and Kues, 1979, p. 226). Lucas (1981), however, has given the correct interval of the Cerrillos local fauna as 369-424 m (1,210-1,391 ft) above the base of the Galisteo.

The strata between the Cerrillos local fauna and the lowest titanothere occurrence of the Tongue local fauna (fig. 4, unit 74, locality C5) have so far failed to produce fossil remains diagnostic of their age; locality C4 has produced only indeterminate bone fragments. Because of this lack of identifiable fossils between the strata that produce the Cerrillos and Tongue local faunas, Lucas and Kues (1979, p. 228) concluded that "it is not certain whether Galisteo deposition was essentially continuous throughout the Eocene or whether major hiatuses exist between the lower and upper Eocene strata." This uncertainty remains. All the sandstones and conglomerates in the medial two-thirds of the Cerrillos section have

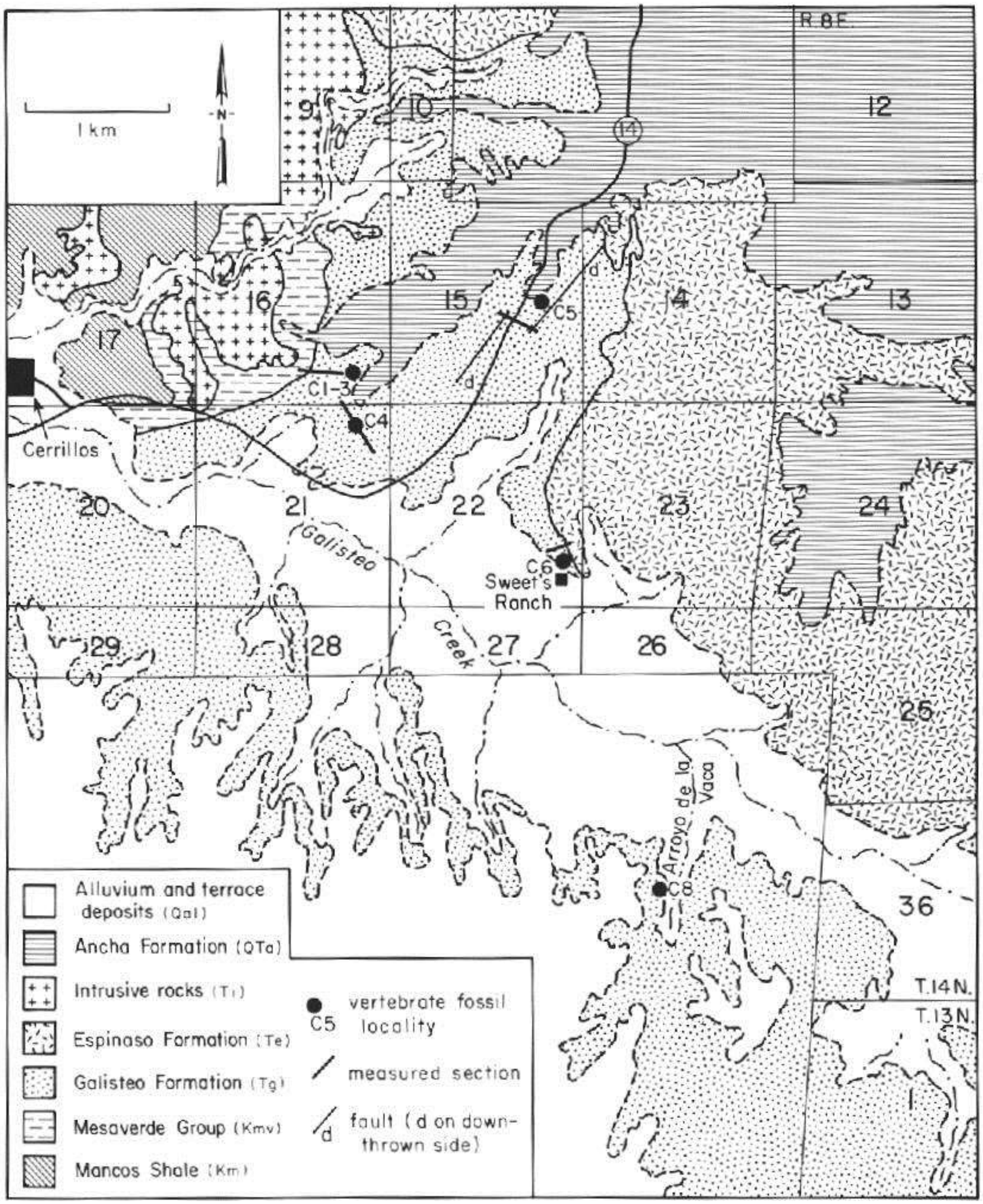

FIGURE 3—GEOLOGIC MAP OF AREA EAST OF CERRILLOS SHOWING VERTEBRATE-FOSSIL LOCALITIES AND LOCATION OF MEASURED SECTION IN FIG. 4. Geology modified from Disbrow and Stoll (1957) and Bachman (1975).

scour-and-fill bases and evidently represent local unconformities. Significant changes in depositional regime, such as the conglomerate of unit 66 (fig. 4 and fig. 5C) also may represent significant breaks in deposition. Without identifiable fossils, however, evaluating the precise temporal significance of these unconformities is impossible.

The lowest occurrence of large titanothere remains in the Cerrillos section (fig. 4, locality C5) extends the stratigraphic range of the Tongue local fauna (Lucas and Kues, 1979) downward to include the upper 231 m (758 ft) of the Galisteo (Lucas, 1981).

3) Upper sandstones—The upper 186 m (610 **ft)** of the Cerrillos section (fig. 4, units 77-83) are mostly coarse-grained to conglomeratic, arkosic sandstones (fig. 5E). Near the middle of these sandstones, a distinctive pebbly horizon with numerous fossil logs (fig. 5D) is here considered equivalent to Gorham's (1979) and Gorham and Ingersoll's (1979) upper yellow pebbly sandstone member in the Hagan Basin. **I** have collected some bone fragments from this horizon, but all identifiable specimens appear to have been collected already by T. E. White (MCZ, specimens now evidently lost) and **T.** Galusha (AMNH). I cannot definitely relocate their localities, but Galusha's unpublished field notes in the AMNH indicate that the specimens he collected at Sweet's Ranch and Arroyo de la Vaca ("La Baca Wash") south of the Galisteo Creek came from this horizon. White's unpublished field notes in the MCZ (see later discussion) also suggest the same provenance.

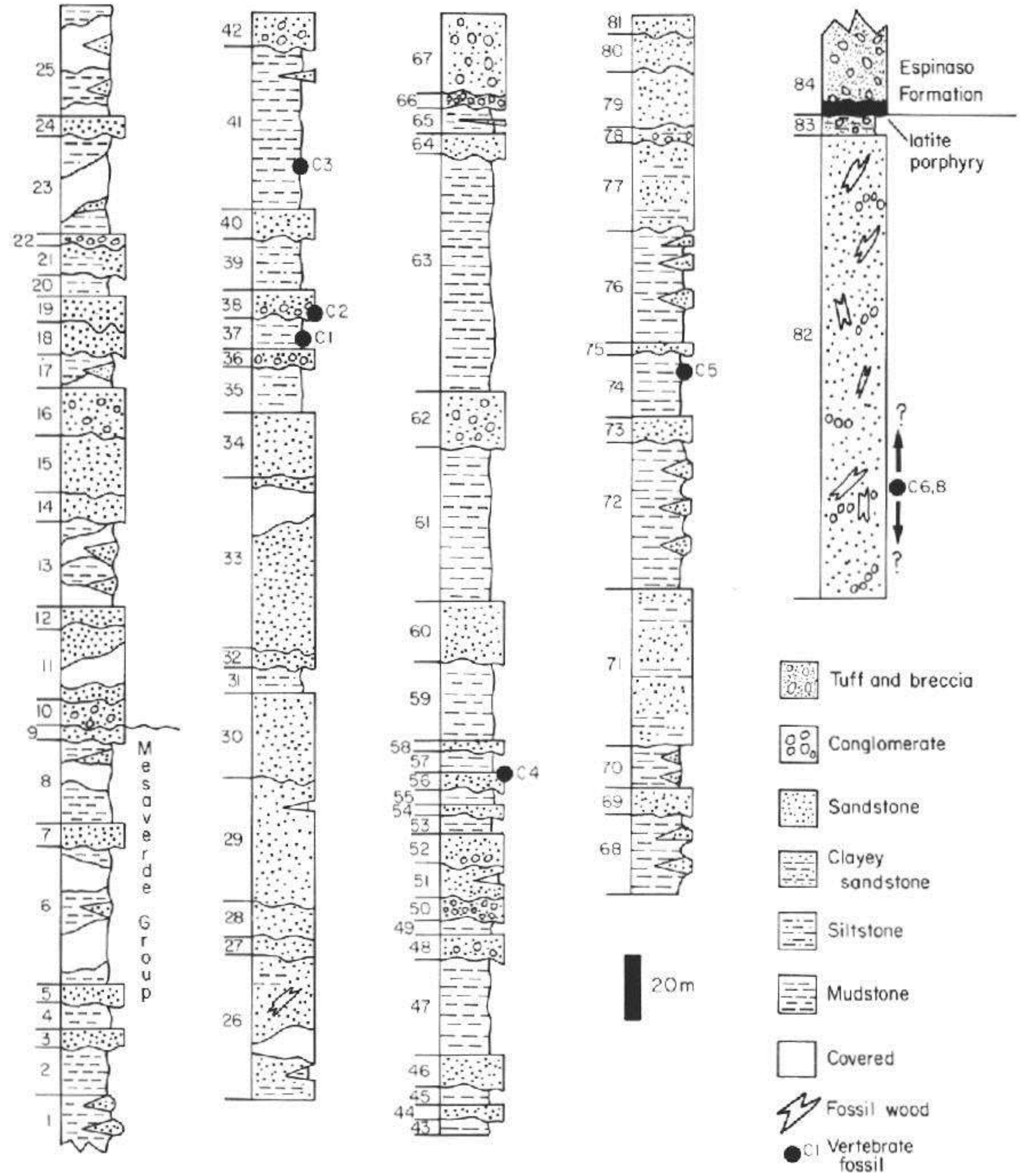

FIGURE 4—MEASURED TYPE SECTION OF GALISTEO FORMATION EAST OF CERRILLOS. Location given in fig. 3; descriptions of lithologic units, appendix 1.

Minor disagreement exists over the placement of the Galisteo Formation-Espinaso Formation contact in the Cerrillos area as well as in the headlands of Arroyo del Tuerto (see later discussion). I follow Stearns (1943) and place the Galisteo-Espinaso contact at the base of the lowest major flow of latite porphyry in the Cerrillos area (figs. 4, 5F). Disbrow and Stoll (1957), however, placed the contact at the base of a 5-m (16-ft)-thick transition zone of tuffaceous clay and sandstone (fig. 4, unit 83). Tuffaceous clays and volcanic fragments, however, are common in the uppermost beds of the Galisteo (Stearns, 1943, 1953a). Clearly the changeover from the deposition of fluvial sandstones and mudstones typical of the Galisteo to the deposition of flows, tuffs, and volcaniclastic debris of the Espinaso was not abrupt (Stearns, 1953a; Disbrow and Stoll, 1957). Placing the Galisteo-Espinaso contact at the first major flow or tuff insures that the contact between the two formations is readily mappable. Such placement seems to me to be a more practical stratigraphic decision of a choice that admittedly is somewhat arbitrary.

Headlands of Montoya Arroyo

A single locality in the headlands of Montoya Arroyo has produced the distal end of a large titanothere humerus (UNM-B-1503) and is included in the Tongue local fauna. This locality is in the upper yellow pebbly sandstone member of the Galisteo Formation in the NW 1/4 NE 1/4 sec. 19, T. 14 N., **R. 6 E. Gorham (1979)**

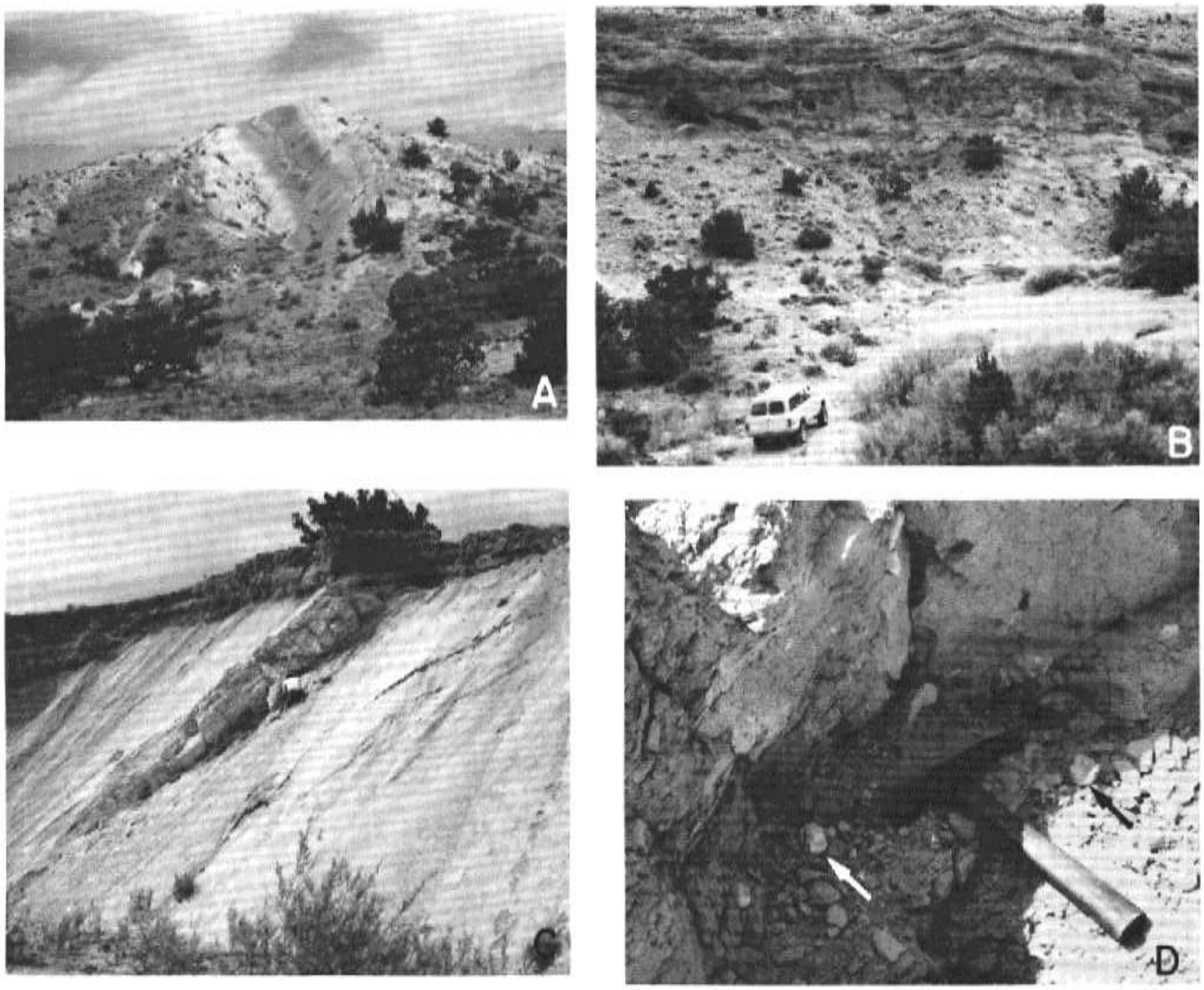

FIGURE 8—GALISTEO AND ESPINASO FORMATIONS IN HEADLANDS OF ARROYO DEL TUERTO: **A)** steeply dipping mudstones and sandstones of upper part of Galisteo Formation, SW ¼NW ¼ sec. 4, T. 13 N., R. 6 E.; **B)** lower part of Espinaso Formation in NE ¼SW ¼ sec. 4, T. 13 N., R. 6 E.; **C)** steeply dipping mudstones of upper part of Galisteo Formation surrounding claystone bed (in high wall man is facing) of locality T4, Stearns' quarry; **D)** close-up view of locality T4; arrows indicate bone fragments, rock hammer is 28 cm long.

of the Galisteo Formation in the Windmill Hill area has been described by Renick (1931), Galusha (1966), Slack (1973), Black and Hiss (1974), and Lucas (1980, 1982).

In the Windmill Hill area, the Galisteo Formation unconformably overlies the Cretaceous Mancos Shale (fig. 11B) and Menefee Formation of the Mesaverde Group (fig. 11A). The lowest stratum of the Galisteo is a 2-20-m (7-65-ft)-thick conglomerate (figs. 10, 11A- C); at least four erosional unconformities are present within this conglomerate (Slack, 1973; Lucas, 1982). Approximately 20 m (65 ft) of sandstone, siltstone, and mudstone overlie this conglomerate, and two localities (W 1, W2) in these strata have produced large titanothere remains (fig. 10). The succeeding strata of the Galisteo Formation are mostly covered by soil and alluvium until a prominent sandstone ridge crops out in NW 1/4 sec. 11, T. 14 N., R. 1 E. (fig. 9). In the middle of these sandstones is a distinctive horizon of yellow, arkosic, coarse-grained to conglomeratic sandstone containing numerous petrified logs (fig. 10, unit 18; fig. 11D). Fossil localities in this sandstone (W3, W4) have produced turtle, large titanothere, and artiodactyl remains; most **AMNH** localities in the Windmill Hill area are from this unit (appendix 2). Lucas (1980, 1982) has assigned this sandstone horizon to Gorham's upper yellow pebbly sandstone member of the Galisteo Formation. Large titanothere fossils also have been recovered from the mudstones and sandstones overlying the upper yellow pebbly sandstone in the Windmill Hill area (localities W5 and W6). The stratigraphically highest locality (W6) is within 6 m (20 ft) of the Galisteo-Zia Sand Formation contact (fig. 10).

The Zia Sand Formation unconformably overlies the Galisteo Formation in the Windmill Hill area (figs. 10, 11E-F). Fossil mammals from the Zia Sand in this area indicate that the Zia is Miocene in age (Galusha, 1966; Gawne, 1975, 1976).

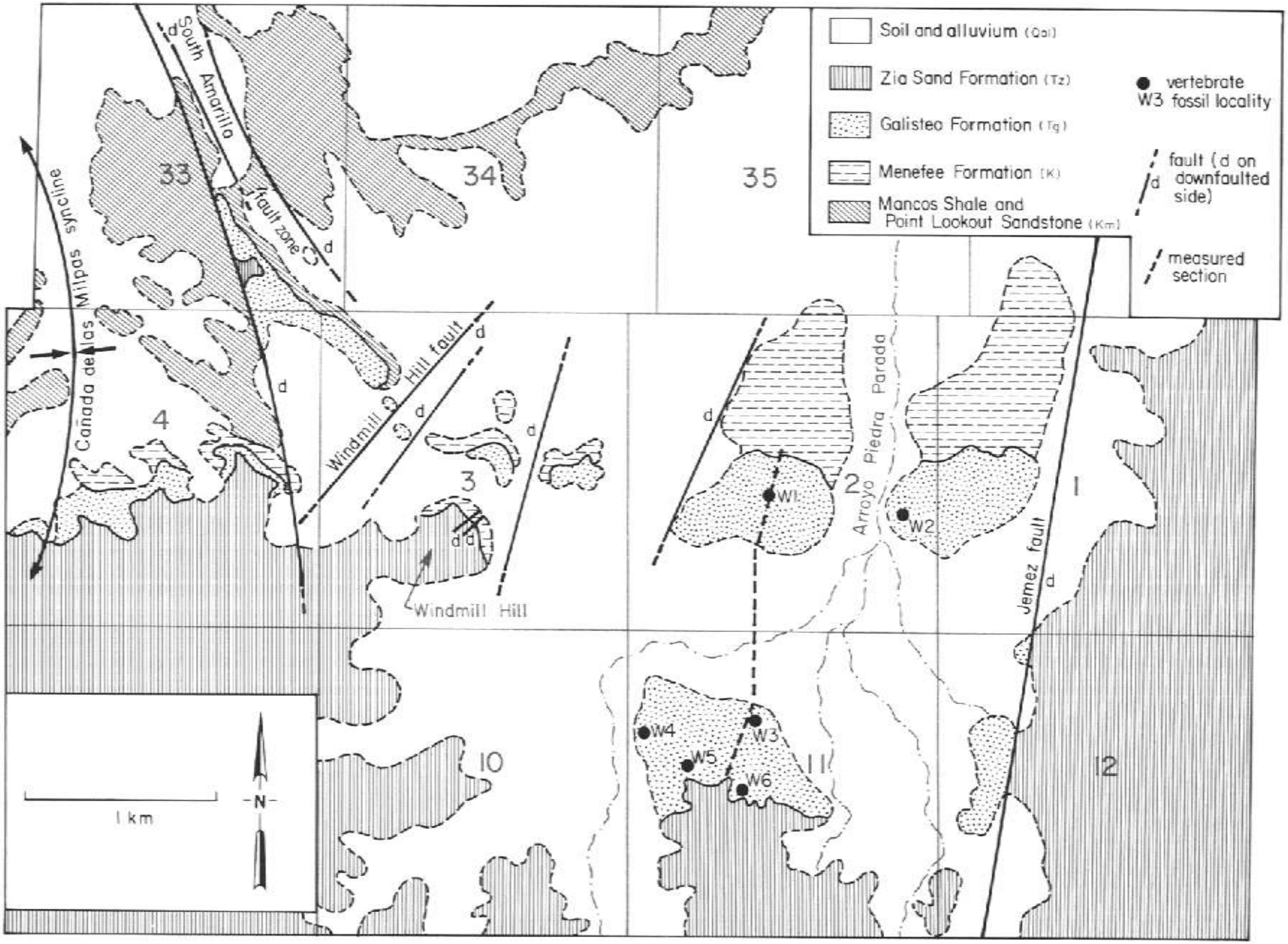

FIGURE 9—Geologic map of Windmill Hill area, showing vertebrate-fossil localities and location of measured section in fig. 10; geology modified, in part, from Galusha (1966) and Slack (1973).

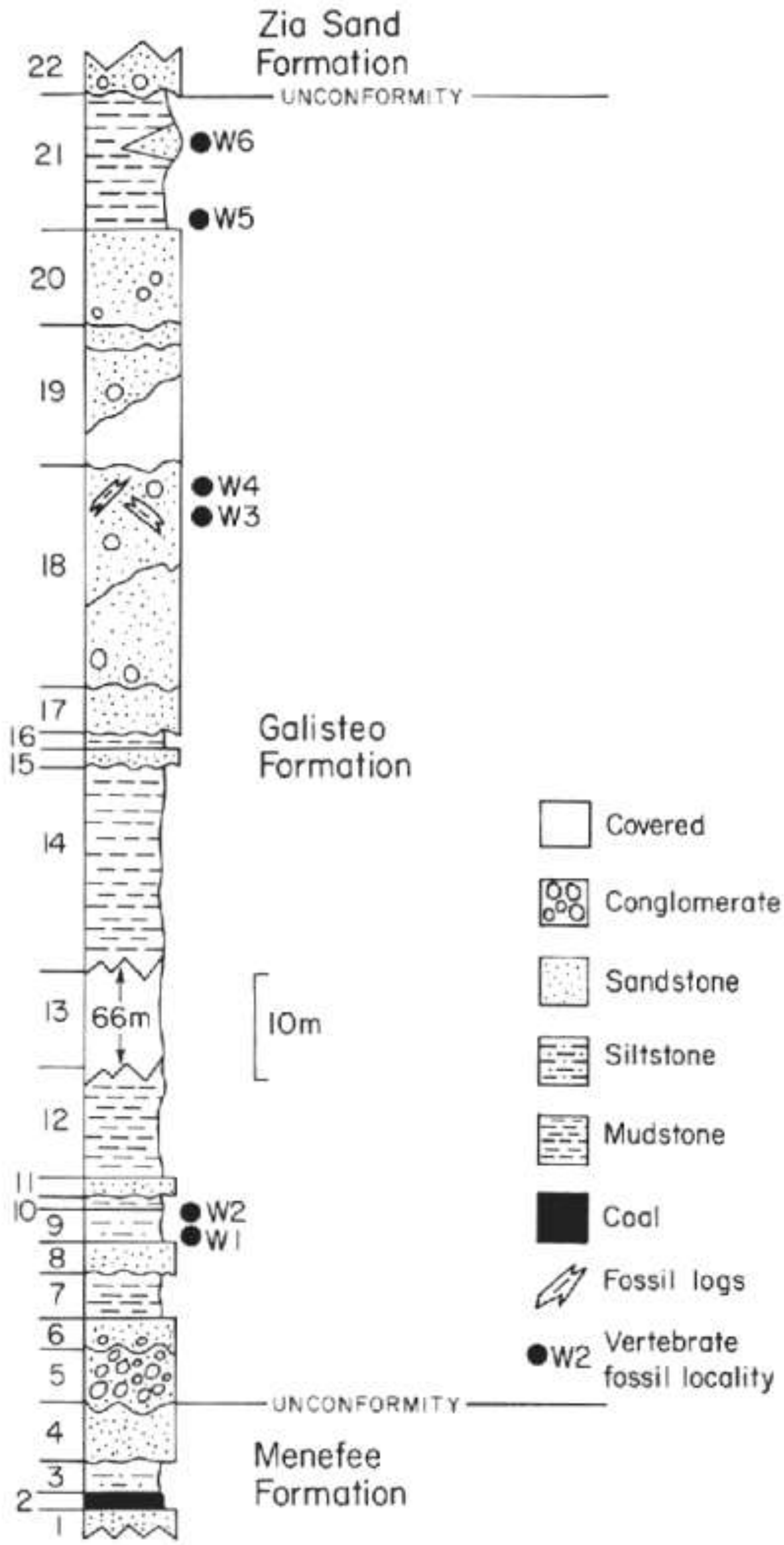

FIGURE 10—Measured section of Galisteo Formation in Windmill Hill area; see fig. 9 for location of section and appendix 1 for descriptions of lithologic units.

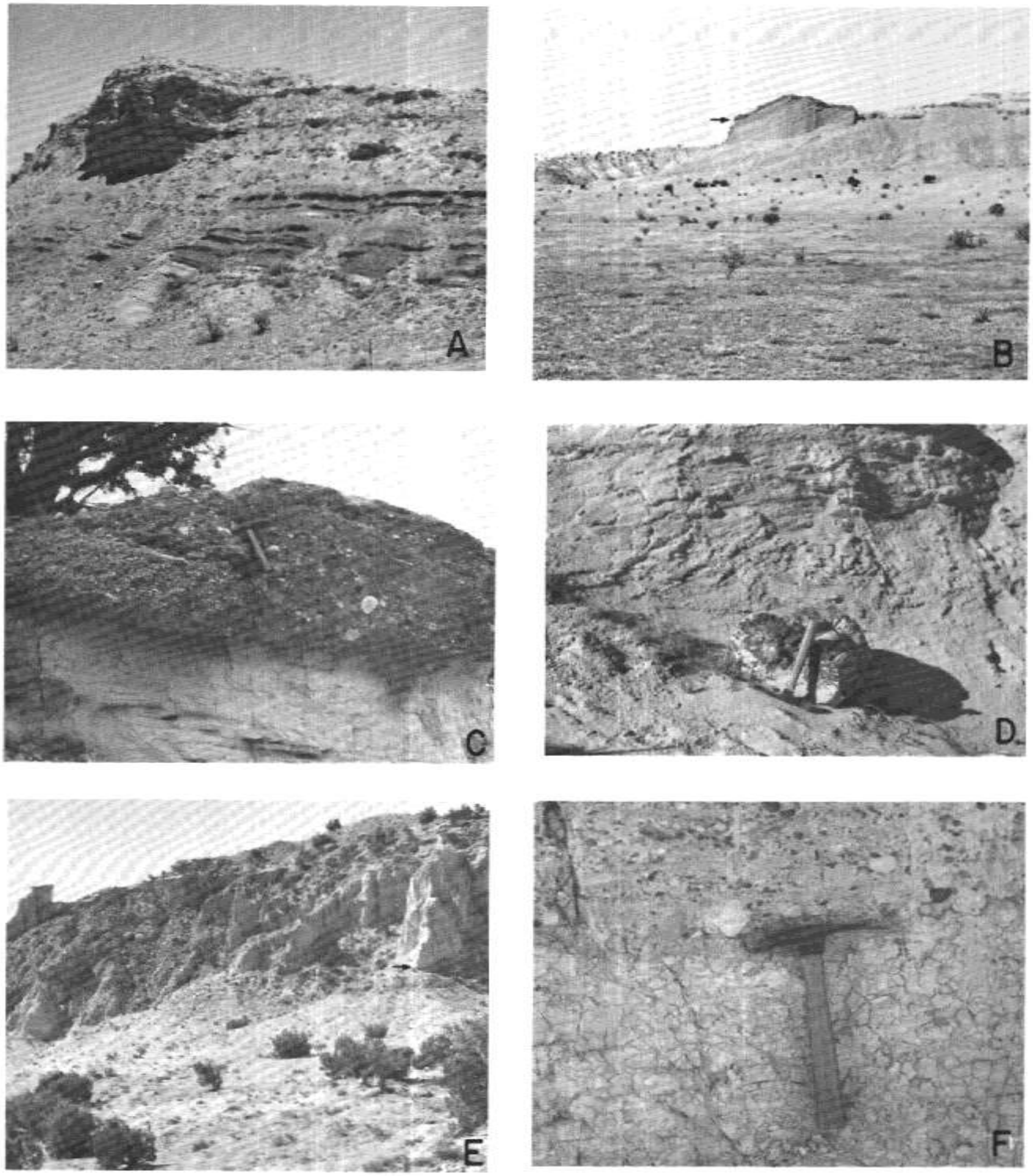

FIGURE 11—GALISTEO FORMATION AND ADJACENT FORMATIONS IN WINDMILL HILL AREA. **A)** basal conglomerate of Galisteo Formation overlying interbedded sandstones, siltstones, mudstones, and coal of Menefee Formation (arrow indicates contact), SE¼NE¼ sec. 3, T. 14 N., R. 1 E.; **B)** basal conglomerate of Galisteo Formation overlying steeply dipping shales of Mancos Formation (arrow indicates contact), NE¼NE¼ sec. 3, T. 14 N., R. 1 E.; **C)** basal conglomerate of Galisteo Formation overlying sandstone of Menefee Formation (rock hammer is 28 cm long), SE¼NW¼ sec. 2, T. 14 N., R. 1 E.; **D)** fossil log fragment in upper yellow pebbly sandstone member of Galisteo Formation (rock hammer is 28 cm long), SE¼NW¼ sec. 11, T. 14 N., R. 1 E.; **E)** Zia Sand Formation overlying Galisteo Formation (arrow indicates contact), NE¼SW¼ sec. 11, T. 14 N., R. 1 E.; **F)** close-up view of Galisteo Formation-Zia Sand Formation contact, same location as arrow in **E** (rock hammer is 28 cm long), rock hammer head at contact.

Systematic paleontology

Most remains of fossil vertebrates from the Galisteo Formation are fragments of bones and isolated teeth that defy precise identification (Lucas and Kues, 1979). Other than the titanotheres of the Tongue local fauna, most taxa from the Galisteo are represented by a single specimen. Other than Stearns' quarry and the upper yellow pebbly sandstone east of Cerrillos, only locality CI near Cerrillos has produced significant numbers of vertebrate remains. Screen-washing (McKenna, 1965) of two tons of mudstone matrix from this locality, however, yielded only three identifiable mammal teeth, a somewhat disappointing result. Further weathering and erosion and more diligent and lucky prospecting will disclose additional specimens, but the material described here represents all identifiable material from the Galisteo Formation obtained during the last 40 yrs of sporadic collecting.

In the following descriptions, all measurements are in millimeters unless otherwise stated.

Class OSTEICHTHYES Family LEPISOSTEIDAE Cuvier, 1825

GENUS indeterminate

Fig. 12A

REFERRED SPECIMEN—UNM-GE-080, isolated scale, locality C3, Cerrillos local fauna.

DISCUSSION—UNM-GE-080 is a small, lozenge-shaped scale of a gar but does not provide sufficient morphological evidence to justify even a genus-level identification (Wiley, 1976).

Class REPTILIA

Order TESTUDINES Linnaeus, 1758

Family TRIONYCHIDAE Bell, 1827

GENUS indeterminate

Fig. 12B

REFERRED SPECIMENS—UNM-GE-096, 105, locality C2; 075, locality C3: shell fragments from the Cerrillos local fauna; UNM-GE-094, locality W4; 095, locality W5: shell fragments from the Tongue local fauna.

DISCUSSION—Shell fragments with a rugose, ridge-and-pit surface sculpture are present in both the Cerrillos and Tongue local faunas. This type of sculpturing is typical of trionychids (Gaffney and Bartholomai, 1979).

Family indeterminate

REFERRED SPECIMENS—UNM-GE-088, 100, 102, locality C7; 090, 098, locality C8; 104, locality W5: shell fragments from the Tongue local fauna.

DISCUSSION—Turtle-shell fragments with no surface sculpture are present at some Tongue local fauna localities and are not diagnostic at the family level.

Class MAMMALIA

Order CREODONTA Cope, 1875

Family HYAENODONTIDAE Leidy, 1869

GENUS *Pterodon* Blainville, 1839

Pterodon sp.

Fig. 13F-G

REFERRED SPECIMEN—F:AM 96434, right maxillary fragment with damaged C^1 and M^1, parts of P^{3-4}, complete P^2, alveolus for P^1, and roots of M'; locality C8, Tongue local fauna.

DISCUSSION—Characters that justify assignment of F:AM 96434 to *Pterodon* are: premolars short and relatively high, infra-orbital foramen above P^3, P^3-M^2 rapidly increase in size, M' with small protocone, lack of proximodistal shearing facet on M', lack of distinct lingual cingula on the upper teeth, and size (WI., = 23.8; W = 21.0). These features readily distinguish it from *Hyaenodon* (Mellett, 1977) but less certainly distinguish it from *Hemipsalodon.* According to Mellett (1969), the main distinction between *Pterodon* and *Hemipsalodon is* the presence in *Hemipsalodon* of upper and lower molars that rotate along the proximodistal axis during ontogeny. The teeth of F:AM 96434 are virtually unworn, suggesting that it is a young individual. Hence, it alone provides no evidence of the presence or absence of such rotation. I do not assign F:AM 96434 to *Hemipsalodon* because its teeth lack distinct lingual cingula and its M' is smaller than those of *Hemipsalodon,* but well within the size range of *Pterodon* (Savage, 1965; Mellett, 1969). However, better knowledge of the Galisteo form may later justify its assignment to that genus, possibly as a new, small species. Since the genus *Pterodon* is in dire need of revision (Savage, 1965), I don't believe it would be useful to assign a trivial name to the Galisteo form.

NOTE ADDED IN PROOF—Further preparation and radiographs of F:AM 96434, referred to *Pterodon* sp. above, have convinced me that the interpretation of the teeth present given in fig. 13 is incorrect. The tooth identified as M' actually is P^4, and P^3 corresponds to the two crown fragments identified in fig. 13 as P^3 and P^4. Given this reinterpretation, F:AM 96434 can be assigned confidently to *Hemipsalodon grandis* as defined by Mellett (1969). Note that this reidentification does not contradict assignment of a Duchesnean age to the Tongue local fauna, since *Hemispsalodon* is known from localities of both Duchesnean and Chadronian age (Mellett, 1969).

Order CARNIVORA Bowdich, 1821

GENUS indeterminate

DISCUSSION—T. E. White's unpublished field notes in the MCZ have the following entry for 20 August 1938:

> Visited Sweet's Ranch near Los Cerrillos and took out titanothere jaws and *Cynodictus (sic) jaw,* also some

petrified wood. Bone and wood in coarse, friable, crossbedded sandstone, sandstone about 200 ft. thick.

Stearns (1943, p. 310) further reported:

> During the summer of 1939 (sic) Dr. Theodore White, of Harvard University, made a small collection near Sweet's Ranch, east of Los Cerrillos. The material was taken from a sandstone probably less than 200 feet (61 m) below the Espinaso Volcanics, although its precise stratigraphic position is not known. In the collection Dr. White has identified *Teleodus* sp. and *Uintacyon* sp.

Presumably White's identification of *Uintacyon* cited by Stearns refers to the same specimen he called *Cynodictis* in his field notes. I have been unable to locate this specimen; it never was entered into the MCZ collection (C. Schaff, personal communication, 1979). Therefore I do not include *"Uintacyon" in* the faunal list of the Tongue local fauna. The two names White applied to the specimen suggest that it pertained to a late Eocene carnivore, supporting assignment of a late Eocene age to the upper part of the Galisteo Formation (see later discussion).

Order TAENIODONTA Cope, 1876

Family STYLINODONTIDAE Marsh, 1875

GENUS *Ectoganus* Cope, 1874

Ectoganus sp.
Fig. 5B

REFERRED SPECIMEN—UNM-GE-097, partial right humerus, locality C2, Cerrillos local fauna.

DISCUSSION—UNM-GE-097 is a large humerus with a prominent ectepicondylar flange. It is indistinguishable from YPM 27201, a humerus of *Ectoganus* from the lower Eocene Willwood Formation of the Bighorn Basin, Wyoming. Schoch (1981) illustrated and described UNM-GE-097, further justifying its assignment to *Ectoganus.*

Order PANTODONTA Cope, 1873

Family CORYPHODONTIDAE Marsh, 1876

GENUS *Coryphodon* Owen, 1845

Coryphodon sp.
Fig. 12D-E

REFERRED SPECIMENS—UNM-GE-076, tooth fragments; UNM-GE-079, fragment of distal shaft of left humerus: both from locality C3, Cerrillos local fauna.

DISCUSSION—Robinson (1957) reported an upper molar of *Coryphodon* from the lower part of the Galisteo Formation near Cerrillos (see earlier discussion), but I have not been able to relocate this specimen (it was UNM Geology Museum 1670), and apparently it has been lost. Lucas and Kues (1979) mentioned UNMGE-076, large, rugose, and lineated tooth fragments that almost certainly pertain to *Coryphodon.* In addition, UNM-GE-079 is a humerus fragment indistinguishable from humeri of *Coryphodon* (for example, Cope, 1877, pl. 62, figs. I , I a). Obviously the material at hand is not sufficiently complete to allow assignment to a species.

?Order PRIMATES Linnaeus, 1758

Family MICROSYOPIDAE Osborn and Wortman, 1892

GENUS *Microsyops* Leidy, 1872

Microsyops sp.
Fig. 12L

REFERRED SPECIMEN—UNM-GE-110, right M_1 or M_2, locality C1, Cerrillos local fauna.

DISCUSSION—UNM-GE-110 is referable to *Microsyops* (note its distinct and twinned entoconid and hypoconulid) but does not provide sufficient information for a species-level identification. Its size (L = 3.7, AW = 2.1, PW = 2.7) is within the size range of several Wasatchian species of *Microsyops,* including *M. angustidens* and *M. latidens* (Szalay, 1969).

Order RODENTIA Bowdich, 1821

Family PARAMYIDAE Miller and Gidley, 1918

GENUS indeterminate

Fig. 12J-K

REFERRED SPECIMEN—UNM-GE-111, 112, I^1 fragments, locality C1, Cerrillos local fauna.

DISCUSSION—UNM-GE-111 and 112 are two gliriform incisor fragments that have enamel restricted to their anterior faces, have oval cross sections, and are widest immediately behind the enamel cap. These features are characteristic of the gliriform incisors of early Eocene paramyids (Wood, 1962, p. 245, figs. 17E, 21B), but the Galisteo specimens are so incomplete that a more precise identification is impossible.

Order CONDYLARTHRA Cope, 1881

Family HYOPSODONTIDAE Trouessart, 1879

GENUS *Hyopsodus* Leidy, 1870

Hyopsodus powellianus Cope, 1884
Fig. 12G-1

REFERRED SPECIMEN—UNM-GE-078, right dentary fragment with M_{1-2}, locality C1, Cerrillos local fauna.

DISCUSSION—UNM-GE-078 is assigned to *H. powellianus* because of its similarity to the holotype of that species, AMNH 4147, a right dentary fragment with M,_, from the Willwood Formation (lower Eocene) of the Bighorn Basin, Wyoming (cf. Gazin, 1968, pl. 8, fig. 8). The Galisteo specimen (MIL = 5.2; AW =4.1; PW = 3.8) is slightly smaller than AMNH 4147 but falls well within the size range of *H. powellianus* as defined by Gazin (1968). Unlike AMNH 4147, UNM-GE-078 possesses a very small M, paraconid, but minor morphological variation in *Hyopsodus* of this sort thus far has proven to be of little taxonomic utility (West, 1979).

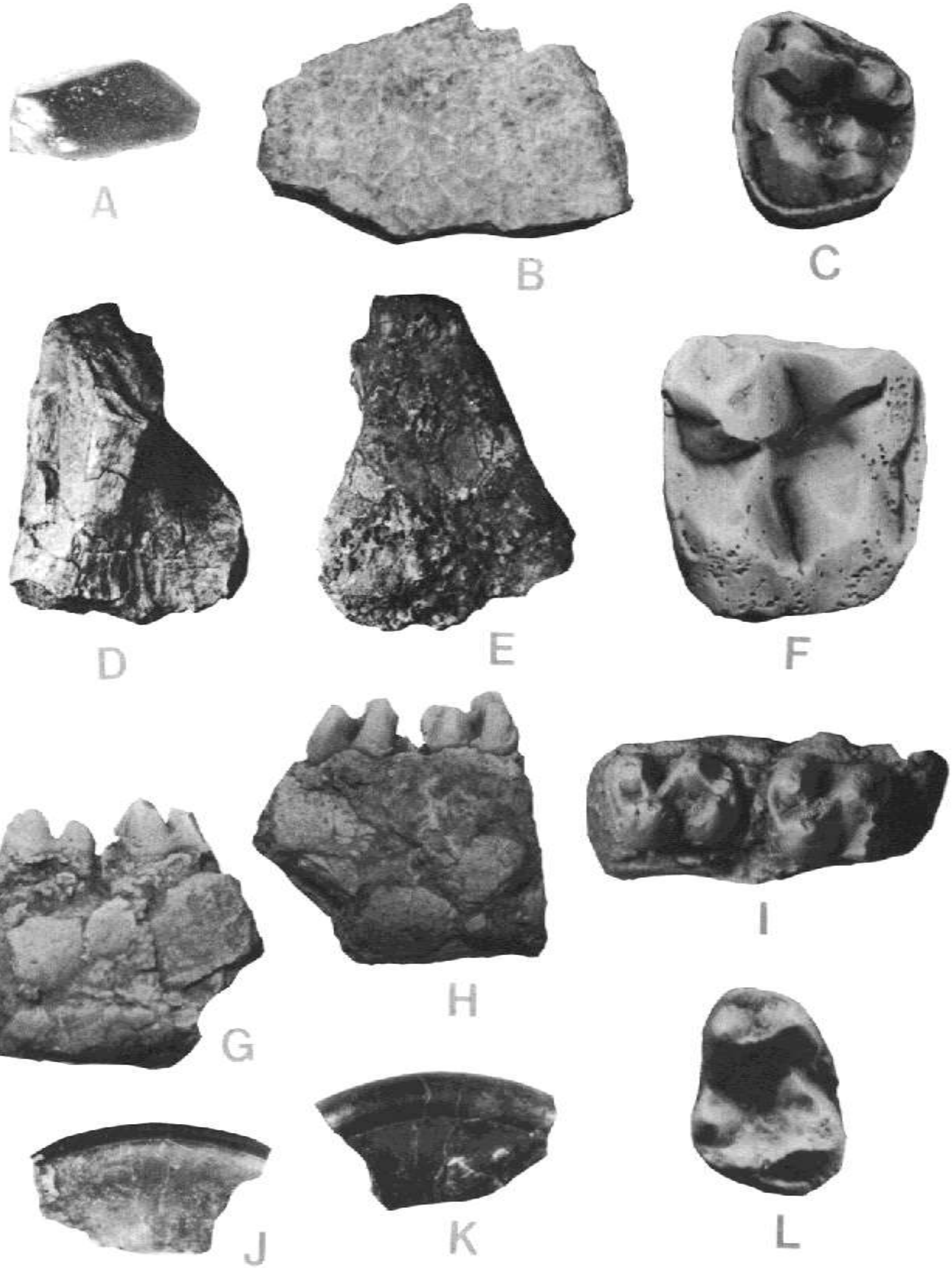

FIGURE 12—FOSSIL VERTEBRATES OF CERRILLOS LOCAL FAUNA: **A)** Lepisosteidae, UNM-GE-080, isolated scale, x3; **B)** Trionychidae, UNM-GE-105, shell fragment, x1.5; **C)** *Hyracotherium* sp., UNM-GE-084, left M^3, occlusal view, x4; **D,E)** *Coryphodon* sp., UNM-GE-079, fragment of distal shaft of left humerus, anterior **(D)** and posterior **(E)** views, x½; **F)** cf. *Homogalax protapirinus*, UNM-GE-077, right M^1 or M^2, occlusal view, x4; **G,H,I)** *Hyopsodus powellianus*, UNM-GE-078, right dentary fragment with M_{1-2}, lingual **(G)**, labial **(H)**, and occlusal **(I)** views, **G** and **H** x3, **I** x4; **J,K)** Paramyidae, UNM-GE-111, left I^1 fragment, lateral views, x5; **L)** *Microsyops* sp., UNM-GE-110, right M_1 or M_2, occlusal view, x10.

Order PERISSODACTYLA Owen, 1848

Family ISECTOLOPHIDAE Peterson, 1919

GENUS *Homogalax* Hay, 1899

cf. Homogalax protapirinus (Wortman, 1896)
Fig. 12F

REFERRED SPECIMEN—UNM-GE-077, right M' or M^2, locality C2, Cerrillos local fauna.

DISCUSSION—UNM-GE-077 is a relatively large tooth (L= 10.8; estimated W = 12.1) missing most of its labial margin. Its large size and relatively well-developed lophs suggest assignment to *Homogalax* instead of *Hyracotherium* (cf. Radinsky, 1963). However, the presence of a distinct paraconule on the Galisteo specimen is a feature not typically seen in *Homogalax* (Radinsky, 1963). Thus I refer it only tentatively to *H. protapirinus,* the only species of the genus recognized by Radinsky (1963). McKenna (1960) and Froehlich and Reser (1981) discussed similar problems when referring isolated teeth to *Homogalax.*

Family EQUIDAE Gray, 1821

GENUS *Hyracotherium* Owen, 1840

Hyracotherium sp.
Fig. 12C

REFERRED SPECIMEN —UNM-GE-084, left M^3, locality C1, Cerrillos local fauna.

DISCUSSION—UNM-GE-084 is a medium-sized upper molar (L = 7.3; W = 8.8) with a trapezoidal outline, small parastyle, no mesostyle, moderately developed lophs, distinct intermediate conules, and a shelflike cingulum that surrounds most of the tooth crown. The specimen is readily recognizable as an M^3 of *Hyracotherium.* However, an isolated M^3 of *Hyracotherium is* not sufficient to justify a species-level identification (Kitts, 1956).

Family BRONTOTHERIIDAE Marsh, 1873

DISCUSSION—The taxonomy of the titanotheres is badly confused. Osborn (1929) last revised the family, and subsequent workers have agreed that he oversplit the titanotheres at the species and genus level. Thus, for example, Osborn (1929, p. 469) recognized seven valid genera of Chadronian titanotheres in North America, but Scott (1940, p. 907) and Clark and others (1967, p. 50-51) have claimed that only two genera, *Menodus* and *Teleodus,* are valid. Clearly a revision of the titanotheres is long overdue; the confused state of their taxonomy has greatly hindered accurate identification and interpretation of the Galisteo titanotheres.

GENUS *Teleodus* Marsh, 1890

DISCUSSION—Salient characters that distinguish *Teleodus* from other titanotheres (Marsh, 1890; Hatcher, 1895; Osborn, 1929; Peterson, 1931; Scott, 1940, 1945) are: 1) Size; other than *T. avus,* specimens referred to *Teleodus* are smaller than the large Chadronian titanotheres subsumed under *Menodus* by Scott (1940) and Clark and others (1967). *Teleodus* is larger than most Eocene titanotheres (exceptions are *Protitanotherium* and *Diplacodon).* 2) A convexity is located on the skull roof of *Teleodus* between the occiput and orbits, unlike the concave-upward skull roofs of most Chadronian titanothcres. 3) The horns of *Teleodus* are small and transversely oval in cross section, unlike the large horns with more rounded cross sections of many other horned titanotheres. 4) Specimens of *Teleodus* generally have three lower incisors and two upper incisors that are button shaped, unlike the spatulate incisors of *Protitanotherium* and other Eocene titanotheres. The incisors of *Teleodus* more closely resemble those of the Chadronian forms, although, unlike *Teleodus,* the Chadronian forms generally lose one or more upper and lower incisors. 5) The canines of *Teleodus* are short and round in cross section, unlike the more elongate canines of most Eocene titanotheres. 6) P^1 often is absent on *Teleodus* specimens and generally an extremely short postcanine diastema is present, unlike most Eocene titanotheres. 7) The premolars of *Teleodus* are more molarized (for example, lower premolar entoconids distinct, upper premolar tetartocones distinct) than those of *Protitanotherium* and other Eoeene titanotheres. 8) Distinct hypocones are present on the NV's of *Teleodus* specimens, unlike the M^3's of other Eocene titanotheres.

Five species of *Teleodus* have been proposed: *T. avus* Marsh, 1890; *T. primitivus* (Lambe, 1908); *T. uintensis* Peterson, 1931; *T. californicus* Stock, 1935, and *T. thyboi* Bjork, 1967.

The type and only known specimen of *T. avus,* YPM 10231, is distinguished readily from specimens assigned to the other species of *Teleodus* by its larger size (table 2), broader cheek teeth, more inwardly slanting labial faces of the cheek teeth, and absence of P,.

Specimens assigned to the other species of *Teleodus* by Lambe (1908), Osborn (1929), Peterson (1931), Russell (1934), Stock (1935, 1938), Scott (1945), Bjork (1967), and Nelson and others (1980) are not so readily distinguishable from each other. *T. primilivus, T. uintensis, T. californicus,* and *T. thyboi* are about the same size (table 2) and are differentiated from each other by characters of the anterior dentition. Most of these characters (number of incisors, canine size, postcanine diastema length, P1 present or absent, and mesostyle present or absent on P°) are variable, even within specimens that a given author has been willing to assign to one species. Indeed, the variation of these characters may in part reflect sexual dimorphism, which in mammals commonly expresses itself by variations in the canine and associated anterior dentition.

A revision of *Teleodus is* needed but beyond the scope of this paper. Therefore, I refrain from formally synonymizing any species. The large sample of *Teleodus* skulls from the Duchesne River Formation near Vernal, Utah, should help to resolve the problems of individual and sexual dimorphic variability in *Teleodus* and thus enable its revision.

Most of the titanothere specimens from the Galisteo Formation are not identifiable with certainty to a genus. Material not identifiable includes all of the postcrania and most of the lower jaw fragments. However, the material that is identifiable pertains to *Teleodus.*

TABLE 2—MEASUREMENTS OF TITANOTHERE DENTITIONS FROM THE GALISTEO FORMATION. Selected specimens of *Teleodus* are included. Asterisks (*) denote approximate measurements of damaged or heavily worn teeth. L, length; W, width; measurements shown in cm.

Specimen	P_2 L	P_2 W	P_3 L	P_3 W	P_4 L	P_4 W	M_1 L	M_1 W	M_2 L	M_2 W	M_3 L	M_3 W	P^2 L	P^2 W	P^3 L	P^3 W	P^4 L	P^4 W	M^1 L	M^1 W	M^2 L	M^2 W	M^3 L	M^3 W
Teleodus cf. *T. uintensis*																								
F:AM 108510													2.48	2.72										
F:AM 108521													1.99*	2.75	2.53	3.64	3.09	4.40	4.50*	4.98	5.97	6.48	7.21	7.31
F:AM 108524													2.85	2.70										
UNM-GE-070			3.17	2.31	3.75	2.69	5.27	3.25	5.97	3.60	8.48	3.61												
Brontotheriidae, indeterminate																								
F:AM 108522	2.41*	1.35*	2.76	2.10*	3.35	2.52	4.44*	2.90*	6.30*	3.20*		3.52*												
F:AM 108523							4.99*	2.34*	6.52*	2.82														
F:AM 108526										3.74*	9.49*	3.98												
F:AM 108531									6.38	3.48		3.43												
MCZ 20255					2.71		3.47		4.56															
MCZ 20268					3.49	2.49																		
UCM no #			1.90*		2.40*		3.00*		3.40*		4.30*													
UCM no #							2.90*		3.80*		4.70*													
UCMP 43165					4.52*		4.98*		6.68*		10.26	3.65												
UCMP 43167																			4.66*	7.30*	5.65*			
UCMP 43184											7.39	3.03												
UNM-GE-069					3.94*	2.75				3.68														
UNM-GE-073													2.61	3.28	2.95	3.86	3.55	4.89						
Teleodus avus																								
YPM 10321 (type)	2.89	2.04	3.83	2.94	4.20	3.75	5.21	3.96	6.67	4.61	10.12	4.64												
T. primitivus																								
NMC 6421 (type)[a]	2.60	1.80	3.20	2.30	3.50	2.70	4.80	2.90	5.80	3.30	8.20	3.30												
T. uintensis																								
CM 11754[b]													2.10	2.65	2.60	3.20	3.50	3.90	4.60	4.50	6.10	5.30	6.50	6.10
CM 11759[c]													2.00	2.40	2.70	2.90	3.00	3.20	3.60	3.90	5.00	4.90	5.50	5.30
CM 11761[c]	2.00	1.10	2.20	1.50	2.60	1.90	3.40	2.30	4.70	2.70	6.50	2.80												
CM 11809 (type)[c]	2.20	1.50	2.40	1.90	3.10	2.20	3.50	2.40	5.00	3.20	7.80	3.20												
T. californicus																								
LACM 2143[d]													1.76*	2.55*	2.36	3.17	2.97	4.19	3.90	4.50	5.20	5.50	6.14	6.17
T. thyboi																								
SDSM 63689 (type)[e]															2.65	3.14	3.38	3.99	4.63	4.58	5.76	5.74	6.04	5.71
SDSM 63690[e]													2.25	2.46	2.68	2.95								

[a]Measurements from Lambe (1908, p. 50-51)
[b]Measurements from Scott (1945, p. 245)
[c]Measurements from Peterson (1931, p. 311-312)
[d]Measurements from Stock (1938, p. 512)
[e]Measurements from Bjork (1967, p. 232)

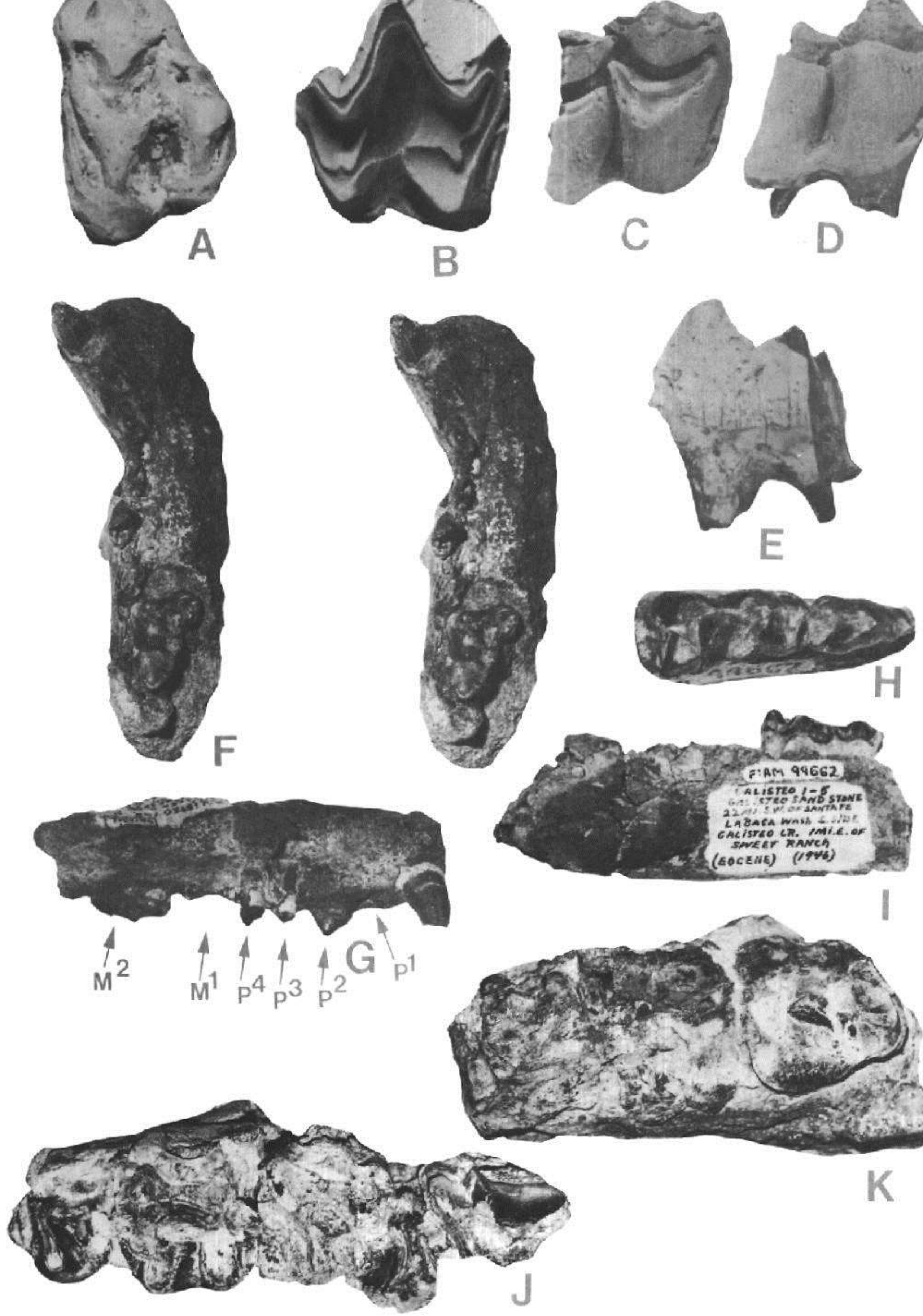

FIGURE 13—FOSSIL VERTEBRATES OF TONQUE LOCAL FAUNA: **A)** *Poabromylus* cf. *P. minor*, MCZ 20269, incomplete left M^1 of M^2, occlusal view, x4; **B)** *Protoreodon* sp., F:AM 108641, incomplete right M^2 (?), occlusal view, x4; **C,D,E)** Protoceratidae, genus indeterminate, UNM-GE-093, incomplete right lower molar, occlusal **(C)**, labial **(D)**, and lingual **(E)** views, x4; **F,G)** *Pterodon* sp., F:AM 96434, occlusal stereophotograph **(F)** and labial **(G)** views, x⅔; **H,I)** *Forstercooperia minuta*, F:AM 99662, left dentary fragment with dP_{2-3}, occlusal view of dP_{2-3} **(H)** and lingual view **(I)**, **H** x⅔, **I** x1.5; **J)** *Amynodon* sp., UCMP 43166, left maxillary fragment with damaged P^4–M^3, x⅔; **K)** *Amynodon* sp., UCMP 43187, left maxillary fragment with M^{1-2} roots and damaged M^3, x⅔.

Teleodus cf. T. uintensis Peterson, 1931
Fig. 14

REFERRED SPECIMENS-F:AM 108510, left P^2, 108521, left P^2, 108524, nearly complete skull with left P^2-M^3 and right P^4-M^3: locality W7; F:AM 108529, partial nasals, 108530, (?) left I_{2-3} and C1: locality C6; UNM-GE-070, right dentary fragment with C alveolus; P_1 root, and P_2-M_3: locality T2; all from the Tongue local fauna.

DISCUSSION-These specimens can be referred to *Teleodus* because they display one or more of the diagnostic features of the genus listed above. Thus, F:AM 108524 has a convexity on the skull roof, distinct upper premolar tetartocones, and M^3 hypocones; F:AM 108521 and 108510 have distinct tetartocones; F:AM 108530 has small buttonlike incisors and a short canine with a round cross section; F:AM 108529 has small nasal horns that transversely are elongate ovals in cross section; UNM-GE-070 (Lucas and Kues, 1979, fig. 5) lacks P,, has a short postcanine diastema and distinct lower premolar entoconids. These specimens are closest in size to *T. uintensis* (table 2), although strictly speaking they cannot be excluded from either *T. thyboi* or *T. californicus* (see above discussion). They establish the presence of *Teleodus* in the Windmill Hill area, Cerrillos area, and the headlands of Arroyo del Tuerto, the three major localities of the Tongue local fauna.

GENUS indeterminate

Fig. 15

REFERRED SPECIMENS-F:AM 108522, right dentary fragment with P_1 alveolus, damaged P_{2-3}, complete P., and damaged M_{1-3}; 108523, right dentary fragment with damaged M_1 and complete M2: both from locality W7; F:AM 108526, right dentary fragment with C alveolus, roots of P_{1-4} and M,, M2 talonid, and complete M_3, locality W8; F:AM 108531, left dentary fragment with M_2 and partial M,, locality C6; MCZ 20255, left dentary fragment with P. and incomplete M_{1-3}, locality T4; MCZ 20268, left P_4, locality T6; UCM no number, left dentary fragment with damaged P_4-M_3 and lower jaw fragment with damaged right P_3-M_3, and damaged left P_4, locality T4; UCMP 43165, left dentary fragment with damaged P_4-M_2 and complete M_3, 43167, maxillary fragment with damaged M^{1-3}: both from locality T4; UCMP 43184, left M_3, locality T5; UNM-GE-069, left P., partial left M_2, and other tooth fragments, locality T3; UNM-GE-073, left P^{2-4} and other tooth fragments, locality T4; assorted catalogued and uncatalogued incomplete and/or isolated postcranial bones in the F:AM, UCM, UCMP, and UNM collections, localities C6, Ml, T4, W7, Tongue local fauna.

DISCUSSION-The majority of titanothere specimens from the Galisteo Formation cannot be assigned with certainty to a genus. Not only is most of the material too incomplete to be diagnostic, but the confused state of titanothere taxonomy makes it difficult to assign even a generic name to lower jaw fragments. The indeterminate specimens belong to four categories: 1) Lower teeth and jaw fragments such as UNM-GE-069 and F:AM 108522, as well as the majority of postcrania, are not distinguishable from remains of *Teleodus uintensis* (Peterson, 1931; Scott, 1945). However, by themselves these remains are not sufficiently complete to exclude their assignment to a titanothere in the size range of *T. uintensis*, such *as Protitanotherium.* 2) Lower jaw fragments such as F:AM 108526 (fig. 15C-D) and UCMP 43165 (fig. 15A-B) and upper teeth such as UCMP 43167 and UNM-GE-073 belong to titanotheres at least as large as the type specimen of *T. avus* (table 2). The presence of a P, in F:AM 108526 and the relatively narrow M_3 *with* a long, noncrescentric hypoconulid of UCMP 43165 suggest that neither can be assigned to *T. avus.* The presence or absence of P_1 is variable in *T. uintensis* and perhaps may also have been variable in *T. avus.* If such variability exists, then F:AM 108526 could be assigned to *T. avus.* UCMP 43165, on the other hand, may more likely belong to *a Menodus* variant. The large upper Galisteo teeth may represent the unknown upper dentition of *T. avus* or *a Menodus* variant. These possibilities, however, require more complete material to be either confirmed or rejected. 3) The two uncatalogued UCM lower jaw fragments (fig. 15E-F), MCZ 20255, and small titanothere postcrania from Stearns' quarry may represent a new, small species of *Teleodus* or a new genus. The lower jaw fragments lack P,, have very short postcanine diastemata, and have relatively molarized P_4's. These features readily distinguish them from all titanotheres from western North America in their size range that I have examined, including *Manteoceras, Metarhinus,* and *Telmatherium.* Except for their small size (table 2), they resemble specimens of *T. uintensis.* However, the specimens are so incomplete and badly damaged that I am unwilling to propose a new taxon based on them.

Family HYRACODONTIDAE Cope, 1879

Subfamily I NDRICOTHERIINAE Borissiak, 1923 **GENUS** *Forstercooperia* Wood, 1939

Forstercooperia minuta Lucas, Schoch, and Manning, 1981 Fig. 13H-I

REFERRED SPECIMEN-F:AM 99662, left dentary fragment with dP_{2-3}, locality C6, Tongue local fauna.

DISCUSSION-Lucas and others (1981a) described F:AM 99662 and justified its referral to *F. minuta*, a species otherwise known only from the late Eocene of Inner Mongolia, China. Eaton (1980, p. 141) reported "*Forstercooperia* sp. (small)" from the middle and upper parts of the Tepee Trail Formation in the southeastern Absaroka Range, Wyoming; this may represent another late Eocene occurrence of *F. minuta* in North America.

Family AMYNODONTIDAE Scott and Osborn, 1883

GENUS *Amynodon* Marsh, 1877

Amynodon sp.
Fig. 13J-K

REFERRED SPECIMENS-UCMP 43166, left maxillary fragment with badly damaged P^4-M^3; UCMP 43187, left maxillary fragment with M^{1-2} roots and damaged

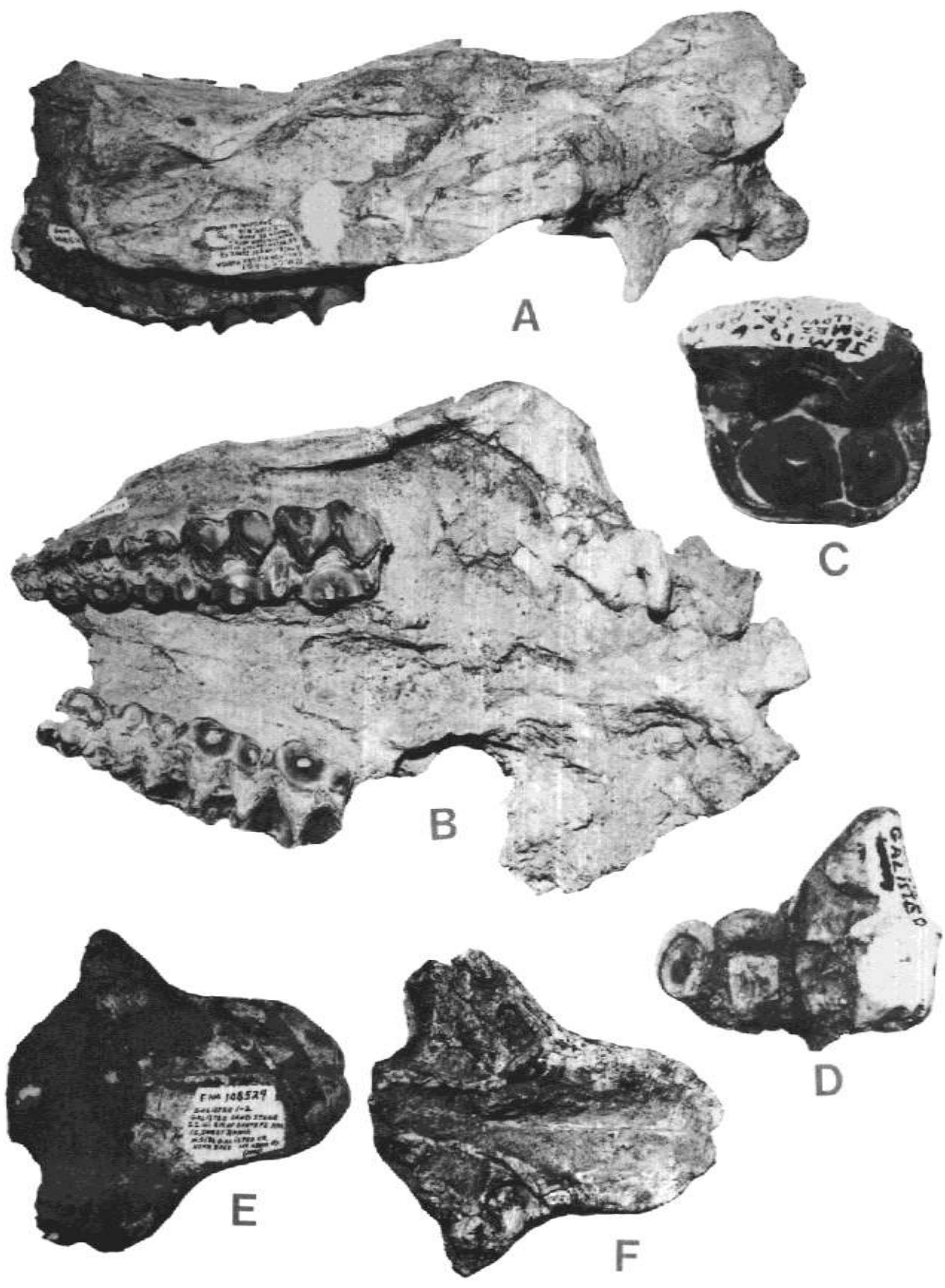

FIGURE 14—*Teleodus* cf. *T. uintensis* from Tonque local fauna: **A,B)** F:AM 108524, nearly complete skull with left P^2-M^3 and right P^4-M^3, left lateral **(A)** and occlusal **(B)** views, x¼; **C)** F:AM 108510, left P^4, occlusal view, x1.5; **D)** F:AM 108530, (?) left $I_{2,3}$, and C_1, anterior view, x 1.5; **E,F)** F:AM 108529, partial nasals, dorsal **(E)** and ventral **(F)** views, x⅓.

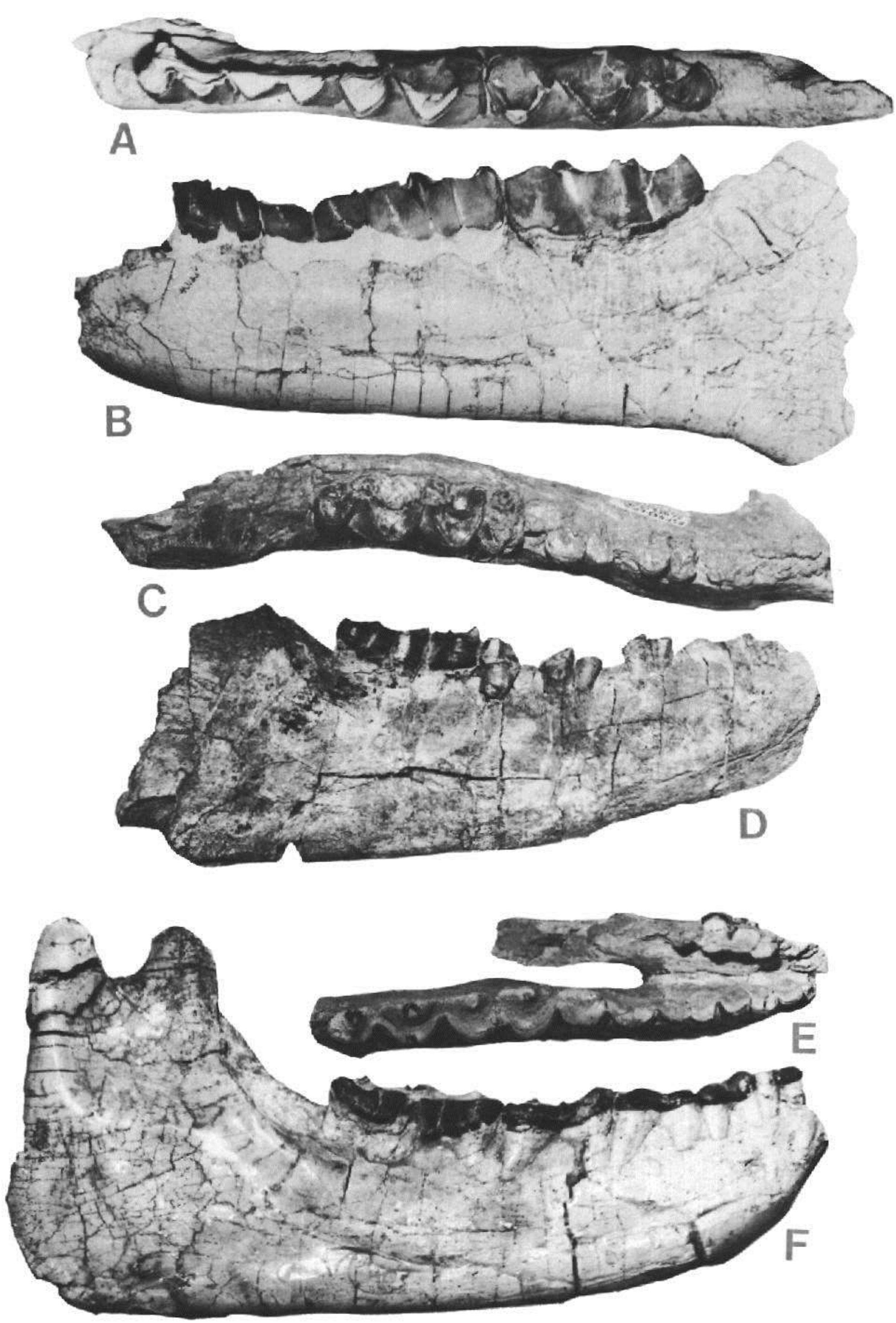

FIGURE 15—BRONTOTHERIIDAE, GENUS INDETERMINATE FROM TONQUE LOCAL FAUNA: **A,B)** UCMP 43165, left dentary fragment with damaged P_4–M_2 and complete M_3, occlusal **(A)** and labial **(B)** views, x⅓; **C,D)** F:AM 108526, right dentary fragment with C alveolus, roots of P_{1-4} and M_1, M_2 talonid and complete M_3, occlusal **(C)** and labial **(D)** views, x¼; **E,F)** UCM no number, incomplete lower jaw with damaged right P_3–M_3 and damaged left P_4, occlusal **(E)** and labial **(F)** views, x½.

M^3 plus assorted fragments of foot bones and other postcrania: both from locality T5, Tonque local fauna.

DISCUSSION—Both UCMP maxillary fragments bear the remains of teeth too small to justify their assignment to *Megalamynodon* or *Metamynodon* (Scott, 1940, 1945). Indeed, their size (UCMP 43166 P^4 estimated L = 25.3, M^1 estimated L = 41.5; UCMP 43187 M^3 estimated L = 45.0, estimated W = 43.5) is very close to the size of *Amynodon intermedius* (Osborn, 1889, p. 509). The relatively weak internal cingulum and short metaloph, unconnected to the protocone, of the P^4 of UCMP 43166 further support assignment *to Amynodon* and also preclude assignment *to Amynodontopsis* (Stock, 1933, 1939). The Galisteo specimens are so poorly preserved, however, that it is impossible to assign a trivial name to them.

Order ARTIODACTYLA Owen, 1848

Family AGRIOCHOERIDAE Leidy, 1869

GENUS *Protoreodon* Scott and Osborn, 1887

Protoreodon sp.
Fig. 13B

REFERRED SPECIMEN—F:AM 108641, incomplete right M^2(?), locality W7, Tonque local fauna.

DISCUSSION—The constricted mesostyle and small, distinct protoconule of F:AM 108641 justify its assignment to *Protoreodon* (Gazin, 1955, p. 47-49). Its relatively small size (estimated L = 8.9; estimated W = 11.3) precludes assignment to *P. pumilus* and places the Galisteo specimen in the size range of *P. parvus, P. pacificus,* and other small *Protoreodon* species (Gazin, 1955; Golz, 1976). The crests of the Galisteo specimen are much more crescentric than those on the type of *P. parvus,* PU 10398 (Scott, 1889, pl. 7, fig. 1), and thus the specimen more closely resembles *P. pacificus.* Without upper premolars it is not possible, however, to definitely assign a specimen to a species of *Protoreodon* (Gazin, 1955; Golz, 1976), and thus I refrain from assigning a trivial name to the Galisteo specimen.

Family PROTOCERATIDAE Marsh, 1891

GENUS *Poabromylus* Peterson, 1931

Poabromylus cf. *P. minor* Wilson, 1974
Fig. 13A

REFERRED SPECIMEN—MCZ 20269, incomplete left M' or M^2, locality T6, Tonque local fauna.

DISCUSSION—MCZ 20269 is a selenodont tooth with thick enamel and a strong internal cingulum, all diagnostic characters of *Poabromylus* (Wilson, 1974, p. 11-12). Its size (estimated L = 7.7; W =11.4) is comparable to that of *P. minor* (Wilson, 1974, table 8), and the very strong internal cingulum of the Galisteo specimen further supports its tentative referral to that species.

GENUS indeterminate

Fig. 13C-E

REFERRED SPECIMEN—UNM-GE-093, right lower molar fragment, locality W5, Tonque local fauna.

DISCUSSION—The posterior crest of the protoconid of UNM-GE-093 and the anterior crest of its hypoconid are directed between the metaconid and entoconid, a feature typical of the Protoceratidae *(sensu* Wilson, 1974). Generic identification of this partial tooth, however, is impossible. It is smaller in size (AW = 6.5) but is similar in morphology to *Poabromylus* (Wilson, 1974). However, UNM-GE-093 also cannot be distinguished from *Leptoreodon* and several other protoceratids (Gazin, 1955; Wilson, 1974). Bjork (1967) discussed a similar problem when identifying isolated protoceratid molars.

Fauna ages and correlation of outcrops

Age of the Cerrillos local fauna

The following taxa presently are included in the Cerrillos local fauna:

Lepisosteidae, genus indeterminate
Trionychidae, genus indeterminate
Ectoganus sp.
Coryphodon sp.
Microsyops sp.
Paramyidae, genus indeterminate
Hyopsodus powellianus
cf. Homogalax protapirinus
Hyracotherium sp.

The joint occurrence of *Ectoganus, Coryphodon, Microsyops,* primitive paramyids, *Hyopsodus,* cf. *Homogalax,* and *Hyracotherium* indicates that the Cerrillos local fauna is Wasatchian (early Eocene) in age (Wood and others, 1941). As Lucas and Kues (1979) pointed out, to attempt a more precise correlation of the Cerrillos local fauna with either the Graybull, Lysite, or Lostcabin "sub-ages" of the Wasatchian is not possible until more taxa of the Cerrillos local fauna are collected. *Hyopsodus powellianus is* a Lysitean to Lostcabinian species (Gazin, 1968) and thus provides slight, but hardly compelling, evidence that the Cerrillos local fauna is post-Graybullian in age. *Homogalax,* early believed to be a Graybullian index fossil (Granger, 1914), also occurs in Lysitean and Lostcabinian horizons (Schankler, 1980; Froehlich and Reser, 1981).

Age of the Tongue local fauna

The following taxa presently are included in the Tongue local fauna:

Trionychidae, genus indeterminate
Testudines, family indeterminate
Pterodon sp.
Teleodus cf. *T. uintensis*
Brontotheriidae, genus indeterminate
Forstercooperia minuta
Amynodon sp.
Protoreodon sp.
Poabromylus cf. *P. minor*
Protoceratidae, genus indeterminate

The joint occurrence of *Amynodon, Teleodus, Protoreodon,* and *Poabromylus* indicates that the Tongue local fauna is late Eocene in age (Wood and others, 1941; Black and Dawson, 1966; Wilson, 1978). *Pterodon* and *Forstercooperia* do not contradict this age assignment because they are known from late Eocene faunas in the Old World (Savage, 1965; Lucas and others, 1981a). *Forstercooperia* also occurs in late Eocene horizons in Utah and Wyoming (Lucas and others, 1981a).

Although assignment of a late Eocene age to the Tongue local fauna is certain, a more precise correlation within the late Eocene is difficult. Whether the Tongue local fauna is late Uintan or Duchesnean in age is a problem for two reasons: 1) the paucity of taxa in the Tongue local fauna and 2) the lack of consensus on the definition and faunal characterization of the Duchesnean land-mammal "age."

Tedford (1970, p. 690-692) and Wilson (1978, p. 33-37) have reviewed the history of differing views on the Duchesnean. I here follow Tedford (1970) and Golz (1976), among others, in considering the Duchesnean to be a distinct land-mammal "age." I define the base of the Duchesnean by the immigration into North America of the genera *Simimeryx, Hendryomeryx, Brachyhyops, Hemipsalodon, Pterodon,* and *Hyaenodon* (for example, Golz, 1976; Mellett, 1977; Webb, 1977; E. Manning, personal communication, 1980). The rationale behind defining land-mammal "age" boundaries by immigration events has been discussed and, in my opinion, justified by Repenning (1967). The evolutionary first occurrence of *Teleodus, Mesohippus,* **and** *Poabromylus* also helps to define the base of the Duchesnean but is not as important as the immigration events. As Repenning (1967, p. 288) pointed out, ". . . evolution is a continuum well suited to defining faunal character but lacking the abrupt changes now sought in definitions of interval boundaries on a continental scale."

The base of the Chadronian, and hence the top of the Duchesnean, is defined by the immigration into North America of *Bothriodon, Mustelavus, Palaeogale, Hoplophoneus, Parictis, Patriomanis,* and others (Emry, 1970; Simpson, 1947). The Duchesnean land-mammal "age" thus is characterized by the Lapoint fauna of the Duchesne River Formation, Uinta Basin, Utah (the "type" fauna of the Duchesnean as defined by Wood and others, 1941) and its correlatives. The best studied correlatives of the Lapoint are the Pearson Ranch local fauna, Sespe Formation, California (Golz, 1976; Golz and Lillegraven, 1977) and the Porvenir local fauna, Chambers Tuff, Texas (Wilson, 1978).

The main problem, then, in assigning the Tongue local fauna to the Duchesnean is the lack of immigrant taxa, other than *Pterodon,* that define the base of the Duchesnean land-mammal "age." However, the presence of *Teleodus* and *Poabromylus in* **the Tongue** local fauna do support its tentative assignment to the Duchesnean (Lucas and Kues, 1979). The presence of *Amynodon* suggests a Uintan age for the Tongue local fauna, since this taxon presumably was extinct (actually or phyletically) by the Duchesnean (Blaek and Dawson, 1966). However, the occurrence of *Amynodon in* the Tongue local fauna may simply represent its range extension upward in time. As Repenning (1967, p. 288) has pointed out, "extinction of taxa is an important historical consideration but is not chronometrically precise because, like faunal and intracontinental zoogeographic evolution, it is not synchronous on a eontinental scale."

In conclusion, I tentatively consider the Tongue local fauna to be Duchesnean in age. I emphasize the tentativeness of this conclusion and hope that later additions to the Tongue local fauna will eliminate this uncertainty.

Correlation of Galisteo Formation outcrops

Gorham (1979; Gorham and Ingersoll, 1979) correlated outcrops of the Galisteo Formation in the Hagan Basin by assuming lateral continuity of the upper yellow pebbly sandstone member. I extend this correlation into the Windmill Hill and Cerrillos areas, also by assuming that the upper yellow pebbly sandstone is one horizon (fig. 16). Although assuming that the upper yellow pebbly sandstone is isochronous over the 70 km (43 mi) that separate the Windmill Hill and Cerrillos areas may be unwarranted, the distinctive lithology and fossil logs of the sandstone suggest that it is one sand body, or a laterally coalesced group of sand bodies, probably deposited by braided streams (Gorham, 1979). The fossils of the Tongue local fauna support this lithologic correlation based on the upper yellow pebbly sandstone because they occur in the sandstone as well as adjacent strata of the upper part of the Galisteo Formation (fig. 16).

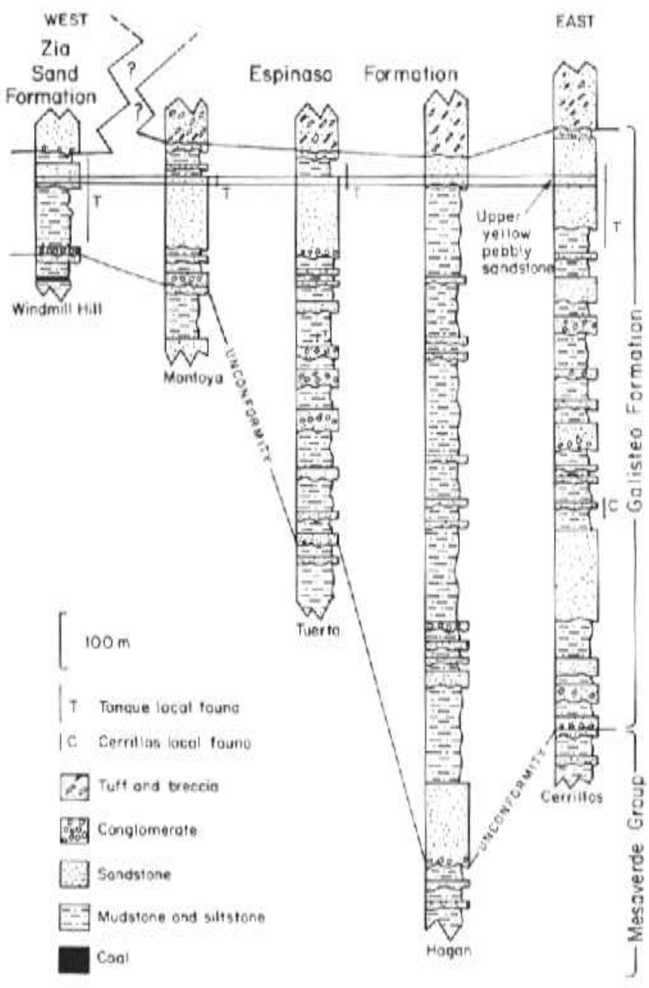

FIGURE 16—Correlation of fossiliferous outcrops of Galisteo Formation in Rio Puerco fault zone (Windmill Hill), Hagan Basin (Montoya, Tuerto, Hagan), and Cerrillos area; Montoya, Tuerto, and Hagan sections after Gorham and Ingersoll (1979).

Correlation of Galisteo Formation with other Eocene formations in New Mexico

Other than the Galisteo Formation, only the San Jose and Baca Formations in New Mexico contain fossils of Eocene age. Various authors have assigned an Eocene age to the El Rito, Palm Park, and Cub Mountain Formations, but without radiometric or fossil evidence it is not possible to verify these age assignments.

The San Jose Formation is exposed in the San Juan Basin and its fossiliferous strata contain two local faunas of Wasatchian age (Lucas, 1977; Lucas and others, 1981b). Although more precise correlation of the Almagre and Largo local faunas of the San Jose Formation is difficult, horizons representing only the Lysite "sub-age" of the Wasatchian appear to be present (Lucas and others, 1981b). Thus, the Cerrillos local fauna of the Galisteo Formation is a correlative of part of the Almagre and Largo local faunas of the San Jose Formation (fig. 17). This correlation supports Kelley and Northrop's (1975) suggestion that parts of the San Jose and Galisteo Formation were deposited at the same time on opposite sides of the Nacimiento uplift (Laramide).

Outcrops of the Baca Formation in south- and west-central New Mexico have produced vertebrate fossils of Bridgerian (middle Eocene) and Duchesnean age (Gardner, 1910; Snyder, 1970; Schiebout and Schrodt, 1981; Lucas and others, 1982). Thus, part of the Baca Formation, particularly fossiliferous outcrops near Carthage and north of Quemado, is a correlative of part of the Galisteo Formation (fig. 17). This supports the suggestion of several workers (for example, Kelley and Silver, 1952; Tonking, 1957) that the deposition of the Baca Formation in part was synchronous with that of the Galisteo Formation.

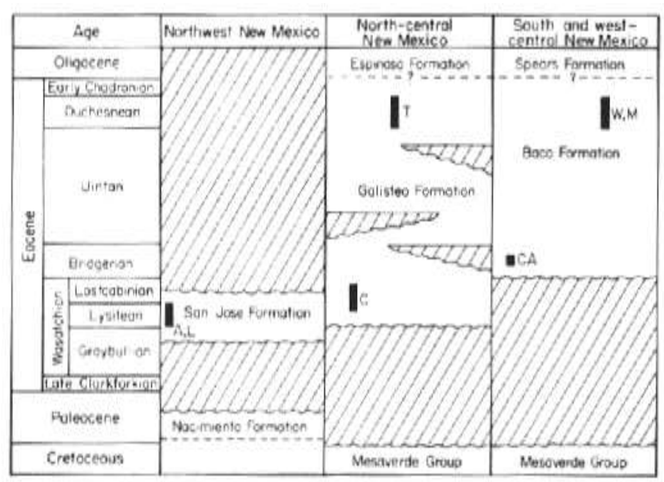

FIGURE 17—Correlation of vertebrate-fossil-bearing formations of Eocene age in New Mexico. Vertebrate faunas (black bars) are: A = Almagre local fauna, C = Cerrillos local fauna, CA = Carthage area titanotheres, L = Largo local fauna, M = Mariano Mesa vertebrates, T = Tonque local fauna, and W = White Mesa vertebrates. Temporal magnitude of unconformities is diagrammatic; after Lucas and others (1982).

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Appendix 1 —Measured sections of Galisteo Formation (figs. 4, 7, 10)

The type section of the Galisteo Formation east of Cerrillos was measured using the tape and Brunton-compass method described by Kottlowski (1965). The sections in the headlands of Arroyo del Tuerto and the Windmill Hill area were measured with a 1.5-m (5.7-ft) Jacob's staff and Brunton compass.

1) Description of measured section (fig. 4) of the upper part of the Mesaverde Group, entire Galisteo Formation (= type section) and the base of the Espinaso Formation east of Cerrillos (see fig. 3 for location). Because of the structural complexity of the outcrops, strike and dip are given whenever they change through the seetion.

Unit	Lithology	Thickness m (ft)
Espinaso Formation		
84	Flow of latite porphyry overlain by tuff and breccia; see Disbrow and Stoll (1957) for further description.	not measured
Galisteo Formation		
83	Sandstone, yellow, clayey and tuffaceous	5.0 (16)
82	Sandstone, yellow, coarse-grained and conglomeratic ("pebbly"); numerous petrified logs; cliff-former; the lower third of this unit contains numerous fossil logs and locality C6; this fossil-log-bearing unit used to offset the section (cf. fig. 3); strike N. 30° W., dip 17° NE.	125.0 (410)
fault (units 81 and 82 crop out on both sides of the fault)		
81	Sandstone, red, coarse-grained	2.7 (9)
80	Sandstone, yellow, coarse-grained; some cross-bedding	9.4 (31)
79	Sandstone, red and brown, coarse-grained	14.5 (48)
78	Sandstone, yellow, coarse-grained and conglomeratic; some green clayey lenses	5.3 (17)
77	Sandstone, green and buff, medium- to coarse-grained; clayey lenses; strike N. 30° W., dip 80° SW. (overturned)	22.5 (74)
76	Mudstone, red; some coarse-grained, red sandstone lenses; sandstone beds are vertical	32.3 (106)
75	Sandstone, gray, coarse-grained	1.1 (4)
74	Mudstone, red; locality C5 near the top of this unit	16.6 (54)
73	Sandstone, red and gray, coarse-grained; strike N. 30° W.; bed is vertical	8.8 (29)
72	Mudstone, red; some lenses of red and gray, coarse-grained sandstone	38.2 (125)
71	Sandstone, gray and green, medium- to coarse-grained; some clayey lenses	40.3 (132)
70	Mudstone, red; some red, coarse-grained sandstone lenses	9.2 (30)
69	Sandstone, red, coarse-grained	7.1 (23)
68	Mudstone, red; some red, coarse-grained sandstone lenses	21.2 (69)
fault (units 67 and 68 crop out on both sides of the fault but dip changes to 80° NW. in the overlying strata)		
67	Sandstone, gray and yellow, coarse-grained and conglomeratic; this unit used to offset the section (cf. fig. 3)	20.0 (66)
66	Conglomerate, gray; mostly quartzite and limestone cobbles up to 15 cm in diameter	3.0 (10)
65	Mudstone, red; a red, coarse-grained sandstone lens in the middle of this unit	5.5 (18)
64	Sandstone, red and gray, coarse-grained; strike N. 40° E., dip 25° NW. (overturned)	5.0 (16)
63	Mudstone, red	58.5 (192)
62	Sandstone, gray, coarse-grained and conglomeratic	13.0 (43)
61	Mudstone, red	40.5 (133)
60	Sandstone, gray and red, coarse-grained; strike N. 40° E., dip 40° NW. (overturned)	14.0 (46)
59	Mudstone, red	20.0 (66)
58	Sandstone, red, coarse-grained	2.5 (8)
57	Mudstone, red	6.5 (21)
56	Sandstone, gray, coarse-grained; locality C4 at the top of this unit	4.0 (13)
55	Mudstone, red	4.0 (13)
54	Sandstone, red, coarse-grained; strike N. 50° E., dip 50° NW.	3.5 (11)
53	Mudstone, red	5.0 (16)
52	Sandstone, brown and gray, coarse-grained and conglomeratic	8.5 (28)
51	Sandstone, red, coarse-grained; mudstone lens in the middle of this unit	9.0 (30)
50	Conglomerate, gray and brown; mostly quartzite and limestone cobbles up to 4 cm in diameter but also some quartz, jasper, lithic and petrified wood fragments	5.0 (16)
49	Mudstone, red	3.0 (10)
48	Sandstone, brown and gray, coarse-grained and conglomeratic	6.0 (20)
47	Mudstone, red	23.0 (75)
46	Sandstone, gray and white, coarse-grained	9.0 (30)
45	Mudstone, red; abundant white calcitic concretions	4.0 (13)
44	Sandstone, red, coarse-grained	4.5 (15)
43	Mudstone, variegated red, green, and blue	4.0 (13)
42	Sandstone, gray and red, coarse-grained and conglomeratic; strike N. 40° E., dip 50° NW. (overturned); this unit used to offset the section (cf. fig. 3)	8.0 (26)
41	Mudstone, red; near the top of this unit is a lens of red, coarse-grained sandstone; locality C3 is in the lower third of this unit	45.0 (148)
40	Sandstone, brown and gray, medium- to coarse-grained; strike N. 20° E., dip 45° SE.	6.5 (21)
39	Siltstone, green and red; abundant white calcitic concretions	12.5 (41)
38	Sandstone, brown and gray, coarse-grained and conglomeratic; locality C2 is at the base of this unit; strike N. 30° E., dip 31° SE.	6.0 (20)
37	Mudstone, red; numerous white calcitic concretions; 4 m (13 ft) above the base of this unit is locality C1	8.0 (26)
36	Sandstone, gray and brown, coarse-grained to conglomeratic	3.0 (10)
35	Siltstone, green, brown, and red; strike N. 20° E., dip 19° SE.	13.0 (43)
34	Sandstone, brown, coarse-grained; strike due N., dip 25° E.	16.0 (52)
33	Sandstone, gray and brown, coarse-grained, partially covered	44.0 (144)
32	Sandstone, brown, coarse-grained; more resistant than unit 33	4.0 (13)
31	Siltstone, brown, gray, and green; strike N. 20° E., dip 35° SE.	5.0 (16)
fault (units 30 and 31 crop out on both sides of the fault)		
30	Sandstone, brown and gray, coarse-grained; strike N. 30° W., dip 28° SE.	21.0 (69)

Unit	Lithology	Thickness m (ft)
29	Sandstone, brown, medium- to coarse-grained; a green mudstone lens is near the top of this unit; strike N. 40° W., dip 30° SE.	33.0 (108)
28	Sandstone, brown and gray, coarse-grained; some planar crossbedding	8.0 (26)
27	Sandstone, dark-brown, coarse-grained	4.0 (13)
26	Sandstone, gray and brown, medium- to coarse-grained; some clayey lenses; some carbonized petrified wood; strike due N., dip 22° E., partially covered by soil	35.0 (115)
25	Mudstone, green and brown; some gray sandstone lenses; partially covered	28.0 (92)
24	Sandstone, dark-green, coarse-grained; appears to be partially metamorphosed to a quartzite	4.3 (14)
23	Siltstone and mudstone, green and red; some sandstone lenses; mostly covered	27.4 (90)
22	Conglomerate, gray and brown; mostly quartz and jasper cobbles up to 3 cm in diameter	2.3 (8)
21	Sandstone, brown and gray, coarse-grained; some clayey lenses	8.2 (27)
20	Siltstone, brown	7.4 (24)
19	Sandstone, brown, medium- to coarse-grained; some crossbedding	5.6 (18)
18	Sandstone, dark-brown, coarse-grained	9.1 (30)
17	Mudstone, brown and gray; a sandstone lens is in the middle of this unit; partially covered	8.2 (27)
16	Sandstone, gray and brown, coarse-grained and conglomeratic	11.2 (37)
15	Sandstone, gray and brown, medium- to coarse-grained	14.9 (49)
14	Sandstone, green and brown, medium- to coarse-grained	5.6 (18)
13	Mudstone, gray and brown; medium- to coarse-grained sandstone lenses; partially covered	21.5 (71)
12	Sandstone, green and brown, medium- to coarse-grained	5.7 (19)
11	Sandstone, brown, medium- to coarse-grained, partially covered	17.4 (57)
10	Sandstone, red and brown, coarse-grained and conglomeratic; strike N. 25° E., dip 75° SE.	6.0 (20)
unconformity		
Mesaverde Group		
9	Sandstone, brown, fine- to medium-grained	4.5 (15)
8	Mudstone, gray and green; a sandstone lens is near the top of this unit; partially covered	20.0 (66)
7	Sandstone, brown, fine- to medium-grained; some clay balls and plant-stalk impressions	5.0 (16)
6	Mudstone, gray and green; in the middle of this unit is a 2-m (6-ft)-thick ledge of gray, fine- to medium-grained sandstone; mostly covered	36.6 (120)
5	Sandstone, gray and brown, fine- to medium-grained	3.6 (12)
4	Mudstone, gray and black, carbonaceous	5.9 (19)
3	Sandstone, gray and brown, fine- to medium-grained	4.5 (15)
2	Mudstone, gray and black, carbonaceous	12.4 (41)
1	Mudstone, green and brown; some lenses of gray, medium-grained sandstone; some dark-brown and black ironstone concretions up to 2 m in diameter; strike N. 40° E., dip 80° SE.	not measured

2) Description of measured section (fig. 7) of the upper part of the Galisteo Formation and base of the overlying Espinaso Formation in the headlands of Arroyo del Tuerto (see fig. 6 for location).

Unit	Lithology	Thickness m (ft)
Espinaso Formation		
7	Tuff and breccia, brown and gray	not measured
Galisteo Formation		
6	Sandstone, gray and brown, fine-grained	8.7 (29)
5	Siltstone, green and gray	2.1 (7)
4	Mudstone, green	3.0 (10)
3	Claystone, green, bentonitic; locality T4 (Stearns' quarry)	2.0 (7)
2	Mudstone, red and green; locality T3 is 3 m (10 ft) above the base of this unit in red mudstone	23.0 (75)
1	Sandstone, yellow, coarse-grained and conglomeratic ("pebbly"); petrified logs abundant, especially in the uppermost 6 m (20 ft) of the unit; localities T1 and T2 are near the top of this unit; some clayey lenses	not measured

3) Description of measured section (fig. 10) of the upper part of the Menefee Formation, entire Galisteo Formation, and base of the Zia Sand Formation in the Windmill Hill area (see fig. 9 for location).

Unit	Lithology	Thickness m (ft)
Zia Sand Formation		
22	Sandstone, gray and white; some crossbedding; some gravel and conglomerate near the base of the formation (see Galusha [1966] for further description)	not measured
unconformity		
Galisteo Formation		
21	Mudstone, green and red; some lenticular yellow sandstones; locality W6 is in one of these sandstones in the middle of this unit; locality W5 is in green mudstone at the base of this unit	13.0 (43)
20	Sandstone, gray and brown, coarse-grained and conglomeratic	9.5 (31)
19	Sandstone, gray and yellow, coarse-grained and conglomeratic; partially covered by soil	13.5 (44)
18	Sandstone, yellow, coarse-grained and conglomeratic ("pebbly"); numerous petrified logs in the upper half of this unit; localities W3 and W4	20.5 (67)
17	Sandstone, yellow, medium-grained	4.5 (15)
16	Mudstone, red	2.0 (7)
15	Sandstone, gray, medium-grained	2.0 (7)
14	Mudstone, red	19.5 (64)

Unit	Lithology	Thickness m (ft)
13	Covered; the red hue of the soils in much of this unit suggests that it is principally underlain by red mudstone	66.0 (216)
12	Mudstone, red- and green-banded	10.0 (33)
11	Sandstone, green and gray, medium-grained	1.5 (5)
10	Mudstone, red; locality W2	1.3 (4)
9	Siltstone, gray and yellow; locality W1	3.5 (11)
8	Sandstone, yellow, medium-grained	3.3 (11)
7	Mudstone, green and red	4.5 (15)
6	Sandstone, gray, coarse-grained and conglomeratic	3.0 (10)
5	Conglomerate, brown, polymodal; largest clasts are 20 cm in diameter; mostly clast supported; poorly sorted though some grading is evident; most clasts are gray quartzite, but fragments of the underlying sandstone are common as well	8.0 ± (26 ±)
unconformity		
Menefee Formation		
4	Sandstone, buff, fine- to medium-grained	5.0 (16)
3	Siltstone, gray, yellow, and brown	3.0 (10)
2	Coal, brown-black, lignitic to sub-bituminous	1.5 (5)
1	Sandstone, gray, medium-grained	not measured

Appendix 2—Locality information

The exact stratigraphic and geographic position of some localities found by collectors from the AMNH, MCZ, UCM, and UCMP could not be relocated. Therefore, acronyms were assigned to those localities and used in the section on systematic paleontology. Locality information, based largely on unpublished field notes in the AMNH and UCMP and a personal communication from C. B. Wood, is presented here:

C7 The *Coryphodon* locality reported by Robinson (1957) in red mudstone of the lower part of the Galisteo Formation, NE¼ sec. 16, T. 14 N., R. 8 E. (see text for discussion).

T5 Localities at about the same stratigraphic level as T1 and T2 in the W½ sec. 4, T. 13 N., R. 6 E., collected by the MCZ and UCMP.

T6 Localities at about the same stratigraphic level as T3 in the W½ sec. 4, T. 13 N., R. 6 E., collected by the MCZ and UCMP.

W7 Localities at about the same stratigraphic level as W3 and W4 in NW¼ sec. 11, T. 14 N., R. 1 E., collected by the AMNH.

W8 Localities at about the same stratigraphic level as W5 and W6 in the NW¼ sec. 11, T. 14 N., R. 1 E., collected by the AMNH.

Type faces:	Text in 10-pt. English Times, leaded one point References in 7-pt. English Times, leaded one point Display heads in 24-pt. English Times
Plates:	Reproduced with 300-line screen
Presswork:	Miehle Single Color Offset Harris Single Color Offset
Binding:	Saddlestitched with soft bound cover
Paper:	Cover on 10-pt. C1S Feedcote Text on 70-lb. Quintessence Dull
Ink:	Cover—PMS 199 Text—Black
Press Run:	750