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LATE CRETACEOUS (MAASTRICHTIAN–LANCIAN) VERTEBRATE PALEONTOLOGY OF THE McRAE FORMATION, ELEPHANT BUTTE AREA, SIERRA COUNTY, NEW MEXICO

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Abstract—Skeletal remains or traces of dinosaurs are known from very few localities in New Mexico. The McRae Formation of the Elephant Butte Reservoir area yielded interesting collections early in the century; unfortunately, most of these collections have been lost and the report of the ceratopsian *Triceratops* cannot be substantiated. Recent discoveries (1981–1986) have shed new light on the age of the fauna and its relationship to faunas elsewhere in the Western Interior.

McRae dinosaurs occur high in the Jose Creek Member and low in the Hall Lake Member. This fauna includes the titanosaurid *Alamosaurus*, *Tyrannosaurus rex*, a fenestrate-frilled ceratopsian, an ankylosaurid, and possibly other taxa. These dinosaurs clearly indicate a late Maastrichtian age for a portion of the McRae, probably equivalent to the Lancian "Land Mammal Age" and clearly equivalent to the lower portion of the Tornillo Group of the Big Bend of Texas, the Naashoibito Member of the Kirtland Shale of the San Juan Basin of New Mexico, and the lower portion of the North Horn Formation of Utah.

The McRae dinosaur fauna has a southern-terrestrial-community character. Elsewhere, this community is dominated by *Alamosaurus*, and contains *Tyrannosaurus rex*, archaic hadrosaurs, and the ceratopsians *Torosaurus utahensis* and/or *Pentaceratops*. This community was distinct from a northern community dominated by the ceratopsian *Triceratops* and containing advanced hadrosaurs, *Tyrannosaurus rex*, and *Torosaurus latus*. Although the precise mechanisms and chronology are unclear, it appears that the archaic character of the southern *Alamosaurus* community was maintained by geographic barriers produced by transgressing and regressing shorelines of the epeiric seaway. Access to new faunal elements became available with withdrawal of the seaway late in the Cretaceous. However, profound modernization of the southern faunal community ceased as dinosaur extinction progressed. The pace and timing of this extinction probably explain the total lack of a terrestrial fauna in the Raton Basin.

INTRODUCTION

Skeletal remains or traces of Late Cretaceous dinosaurs are known from only a few localities in New Mexico. These include the relatively complete and well-studied Campanian–Maastrichtian Fruitland–Kirtland sequence of the San Juan Basin; the late Cenomanian tracks at Clayton Lake State Park; fragmentary material in Turonian rocks near La Joya; and isolated hadrosaur vertebrae reportedly found as float associated with Turonian rocks in the Carthage area. The McRae Formation of the Elephant Butte area yielded interesting and potentially very significant dinosaurs early in the century (Lee 1905, 1907). Despite some rather intensive mapping studies conducted later, discoveries of dinosaur remains virtually ceased (Doyle 1951, Bushnell 1953, Kelley & Silver 1952, McCleary 1960, Thompson 1961, Melvin 1963). Discoveries made within the last five years renewed interest in the area, especially in the thick sequence of strata assigned to the McRae Formation. In this paper we review those discoveries, describe newly prepared McRae fossils, and discuss the relationship of the McRae fauna to other faunas of the Western Interior. Finally, we attempt to demonstrate how the unique character of this fauna is related to the transgressions and regressions of the Late Cretaceous epeiric seaway, and how this influenced Late Cretaceous terrestrial faunas throughout New Mexico.

McRAE FORMATION

Rocks now included in the McRae Formation were recognized as a distinct stratigraphic unit by Lee (1905, 1907). However, Kelley and Silver (1952) first used the name McRae for a thick sequence of nonmarine clastic rocks exposed in the Jornada del Muerto and Cutter Sag. Bushnell (1953, 1955) divided the McRae into two members. The lower of these, the Jose Creek Member, unconformably overlies the Ash Canyon Member of the Crevasse Canyon Formation (Lozinsky 1981, Wallin 1983), included the Mesaverde Group. The Crevasse Canyon Formation is more than 700 m thick (Fig. 1). The Jose Creek Member is about 120 m thick at its type locality and consists of a sequence of sandstone, shale, and conglomerate.

The Jose Creek Member is conformably overlain by the Hall Lake Member, about 884 m thick, and is characterized by abundant purple and maroon shales. A basal conglomerate generally marks the boundary

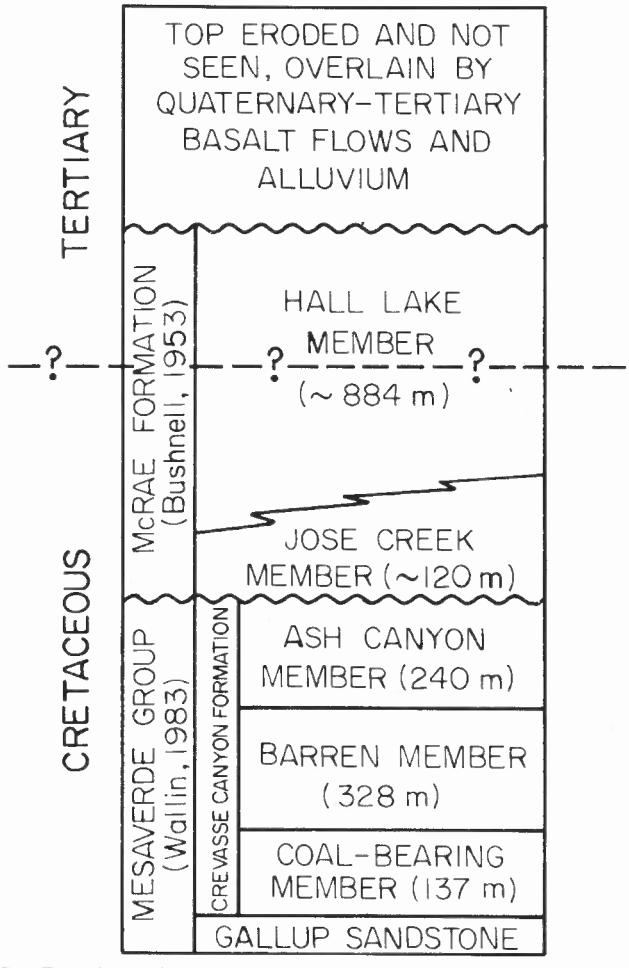


FIGURE 1—Generalized stratigraphic column for the Elephant Butte area (from Lozinsky et al. 1984).

with the Jose Creek. When this conglomerate is absent, the first purple or maroon shale is used as a boundary marker. The top of the Hall Lake is eroded in all areas. Fig. 2 is a generalized geologic map of the Elephant Butte Reservoir area.

VERTEBRATE PALEONTOLOGY: PREVIOUS STUDIES

Lee (1905) reported dinosaur bones in the Elephant Butte area, and at least two additional collections were made during the 1905–1913 period (Kelley & Silver 1952). Lee (1907) noted that J.W. Gidley, a vertebrate paleontologist at the U.S. National Museum, identified *Triceratops* in collections sent to him. According to Kelley & Silver (1952), C.W. Gilmore referred a vertebra he collected at Elephant Butte around 1910 to *Triceratops*. Additionally, based on internal U.S. Geological Survey documents provided by J.B. Reeside Jr., Kelley & Silver (1952) recorded Max Ball's discovery of a partial *Triceratops* skeleton: "At the foot of the east slope of Elephant Butte on the side of a little draw in plain sight from the old Reclamation Service camp. . . ." The bulk of the 1905–1913 collections has been lost or misplaced. Two vertebrae that can be located were discussed by Lozinsky et al. (1984); they are ceratopsian, but their referral to *Triceratops* cannot be substantiated.

In 1968, John Hawley (now at the New Mexico Bureau of Mines & Mineral Resources) and William Seager (New Mexico State University) were notified of the discovery of dinosaur remains at Elephant Butte at a time of very low water level. The specimen was not recovered, but an available photograph (Fig. 3) shows a robust ceratopsian horn. Lake levels have never again been low enough to expose this very important locality.

Beginning in 1981, Lozinsky initiated studies of the geology of the Elephant Butte area and discovered a series of dinosaur localities, some of which are shown in Fig. 1. Although the fossil material from these localities is fragmentary, four taxa can be recognized (Lozinsky et al. 1984). The diversity of the material found is shown in Fig. 4. Of some importance is the presence of the titanaosaurid *Alamosaurus*. Recent preparation of additional material from Lozinsky's sites has increased

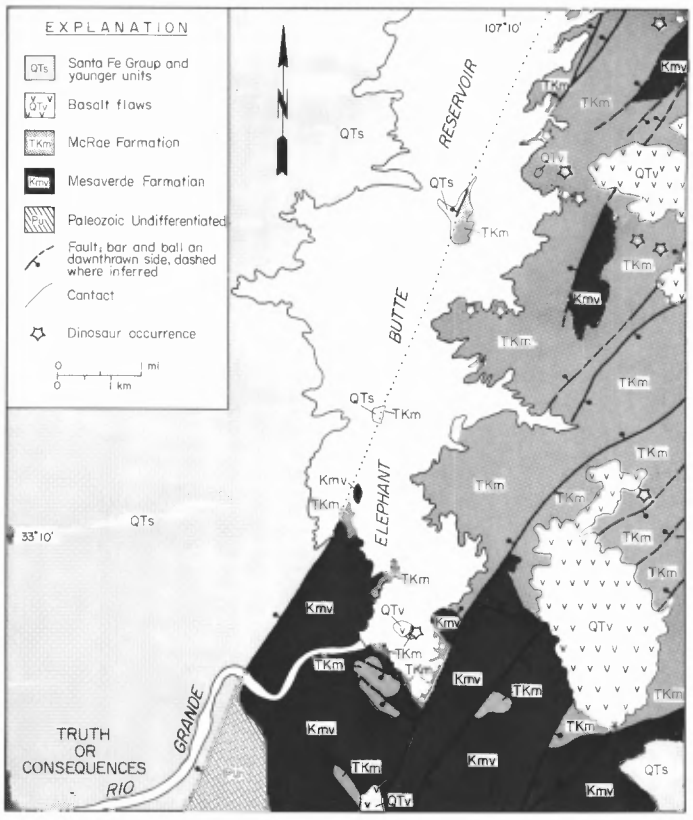


FIGURE 2—Generalized geologic map of the Elephant Butte Reservoir area (after Lozinsky et al. 1984).

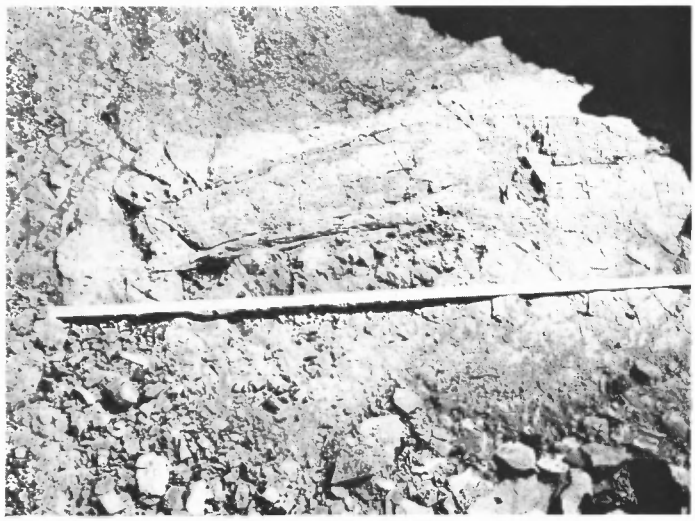


FIGURE 3—Ceratopsian horn seen by John Hawley and William Seager in 1968 at a time of low water at Elephant Butte Reservoir. Horn is approximately 65 cm long.

our understanding of the faunal assemblage (Fig. 5). This material includes the following:

(A) Specimen TKM025 is an 18 × 14 cm bone fragment, flat on one surface and convex on the other. Impressions of blood vessels are discernible on the convex surface. An arcuate margin is preserved that grades laterally into a median ridge.

It is our interpretation that TKM025 represents a segment of the internal margin of a ceratopsian frill. In *Triceratops*, the most common late Maastrichtian ceratopsian, the dorsal surface of the frill is solid and lacks fenestrae; however, a fenestra is indicated by this specimen's arcuate margin. *Torosaurus*, the only other large ceratopsian known from late Maastrichtian deposits, had a fenestrated frill. Although TKM025 is not complete enough to warrant assignment to *Torosaurus*, it does indicate the presence of a ceratopsian with a fenestrated frill in the McRae Formation.

(B) TKM003 is a fragment of a dinosaur upper jaw 6.5 cm in length and 4.5 cm wide at the base. No teeth are preserved, but the form is virtually identical to a portion of a left ceratopsian maxillary in our collections.

(C) TKM029 is an eroded bone fragment 13.5 × 10.5 cm. It is here interpreted as the proximal portion of a femur of a small, gracile dinosaur, possibly a theropod.

(D) TKM026 is a massive bone fragment 15.5 cm long, 14.5 cm wide, 10 cm thick, and roughly rectangular in cross section. It is a segment of a massive dinosaur limb, although not necessarily from a taxon of great overall size.

(E) TKM028 is a rib fragment 64 cm long; the rib is probably 65% complete, although the important proximal articulation is missing. It is apparent from the massive construction, the thickness of the shaft, and the head region that it belonged to a rather large animal.

(F) TKM035 is a large ceratopsian horn, approximately 85% complete and still embedded in a Jose Creek-looking matrix. The specimen is 52 cm long and 7 cm wide at the broken base. It is roughly circular in outline at the base, but becomes more compressed towards the apex. A medial keel is developed along the internal margin, and the horn tapers moderately towards the apex which had to be less than 4 cm in width. The external surface is mildly rugose and several longitudinal grooves are developed. It seems most reasonable to assume that TKM035 is a supraorbital horn.

The specimen was discovered by an amateur collector. We visited the area from which it was collected and noted complex faulting and disjunction of strata. However, we were able to determine that the Jose Creek Member is present in the vicinity and exhibits a lithology similar to that found in the specimen block.

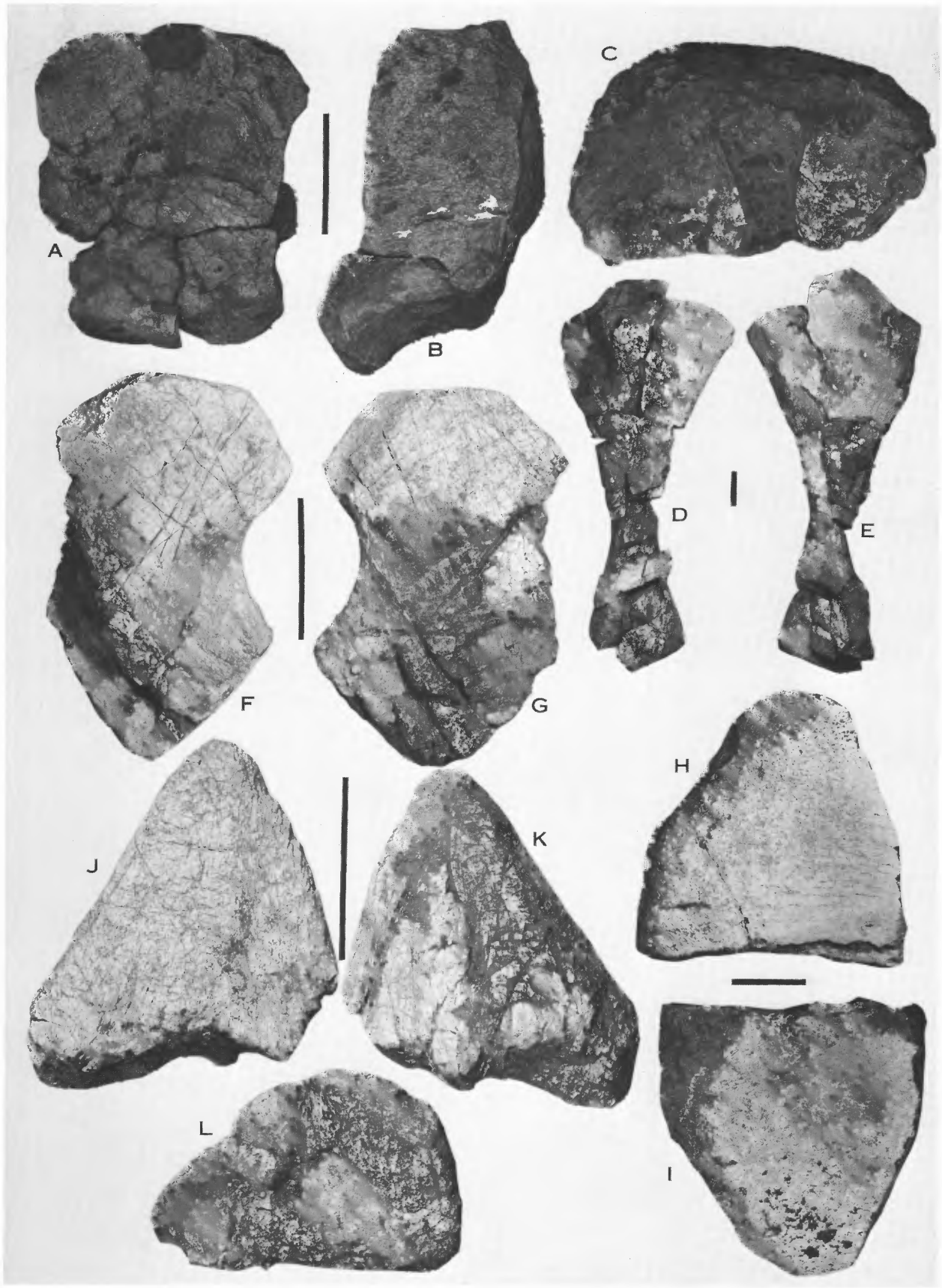


FIGURE 4—McRae dinosaur fossils. **A–C,** TKM001, dorsal theropod centrum, in anterior (A), lateral (B), and dorsal (C) views. **D, E,** TKM007, *Alamosaurus* sp. humerus, in anterior (D) and posterior (E) views. **F, G,** TKM002, ceratopsian coronoid processi lateral, view. **H, I,** TKM020, ceratopsian crest (frill) fragment, in dorsal (H) and ventral (I) views. **J–L,** TKM011, ankylosaur armor fragment, in lateral (J, K) and basal (L) views. Bars equal 5 cm in A–C and F–L, and 10 cm in D and E. From Lozinsky et al. (1984).

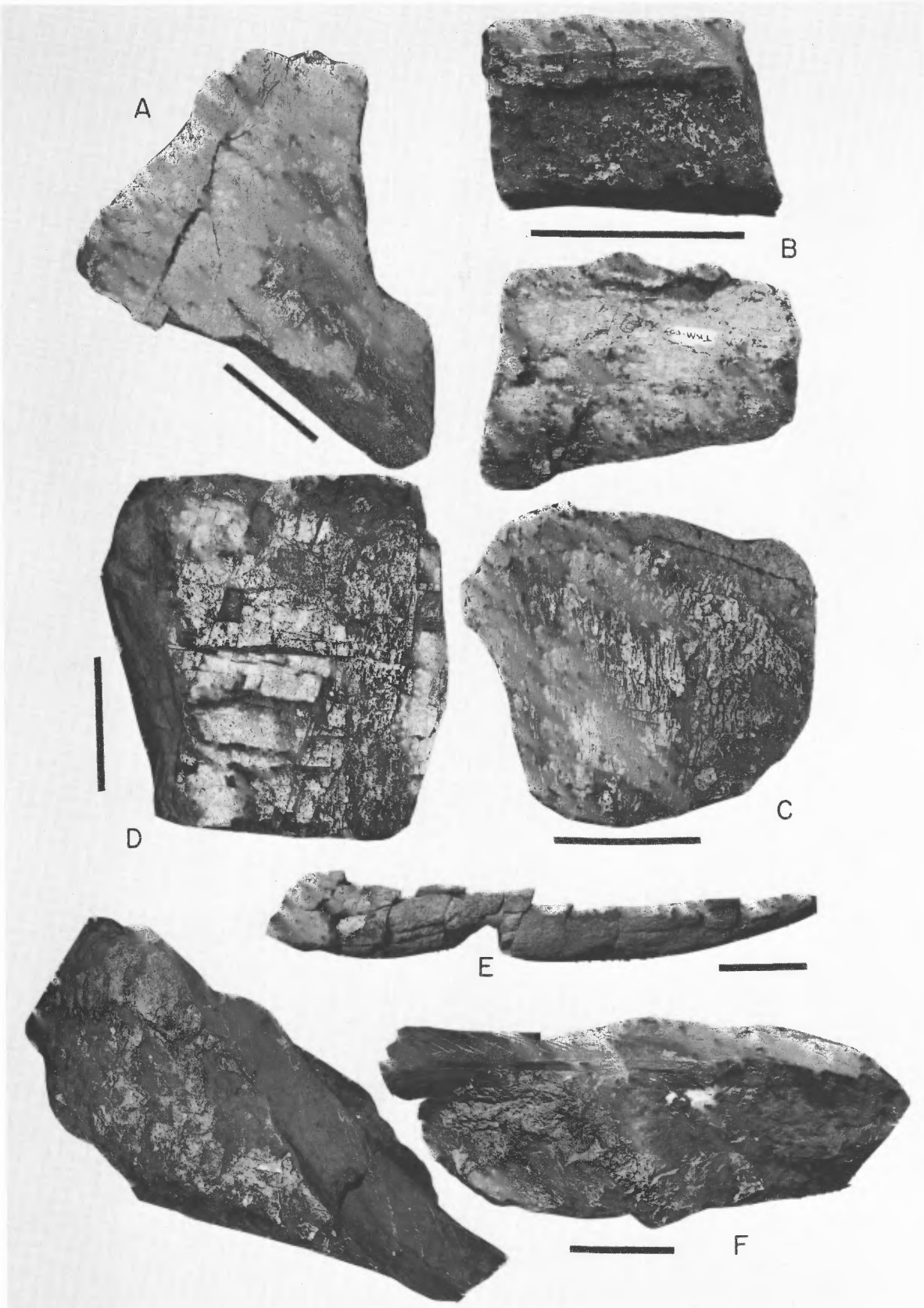


FIGURE 5—**A,** TKM025, ceratopsian frill fragment. **B,** TKM003, dinosaur upper-jaw fragment, in occlusal (upper) and lateral (lower) views. **C,** TKM029, eroded remnant of proximal portion of femur. **D,** TKM026, massive limb fragment. **E,** TKM028, fragmentary dinosaur rib. **F,** TKM035, ceratopsian horn, in lateral (left) and top (right) views. Bars equal 5 cm in A–D and 10 cm in E and F.

In 1983, an incomplete jaw of *Tyrannosaurus rex* was discovered on the east side of the Elephant Butte Reservoir (Gillette et al. in this guidebook). *T. rex*, the fossils collected between 1905–1913, and the Hawley–Seager locality all probably occur low in the Hall Lake Member. Lozinsky's localities lie at or near the boundary between the Hall Lake and Jose Creek Members. No significant hiatus in this interval is likely given the uniform composition of the fauna.

AGE OF THE McRAE AND FAUNAL RELATIONSHIPS

Lozinsky et al. (1984) established that the McRae Formation is in part late Maastrichtian, and in part equivalent to the Lancian "Land Mammal Age" well known from elsewhere in the Western Interior. This view is strengthened by comparisons of the McRae fauna as presently understood to dinosaur faunas known elsewhere. The McRae fauna contains *T. rex*, *Alamosaurus*, and at least one large ceratopsian. The Naashoibito Member of the Kirtland Formation in the San Juan Basin, lower part of the North Horn Formation of Utah, and the lower part of the Tornillo Group (sensu Lawson 1976) of the Big Bend of Texas all contain *Alamosaurus* and the large ceratopsian *Torosaurus* (Gilmore 1922, 1946, Lawson 1976, Lehman 1981). None of these faunas contain the ceratopsian *Triceratops*.

Sloan (1970) reviewed the regional and temporal variation of Campanian–Maastrichtian communities and suggested that the Maastrichtian was characterized by the presence of two dinosaur-dominated communities extending north and south, respectively, from the southern border of Wyoming. We now understand that the separation of these communities probably occurred as far south as the Denver area (Lull 1933, P. Robinson oral comm.). The northern community was dominated by the ceratopsian *Triceratops* and the advanced hadrosaurine *Anatosaurus* (Fig. 6). This *Triceratops* community also contained *Tyrannosaurus rex* and the fenestrated ceratopsian *Torosaurus latus* (Lawson 1976).

The southern community is more archaic in character and retains taxa with late Campanian affinities such as crested duckbill dinosaurs and fenestrated ceratopsians, but adds the titanosaurid *Alamosaurus*. *T. rex* must now be considered a faunal component of the southern *Alamosaurus* community based on its occurrence in the Big Bend (Lawson 1976), Naashoibito Member (M. O'Neill oral comm.), and now the McRae Formation (Gillette et al. in this guidebook).

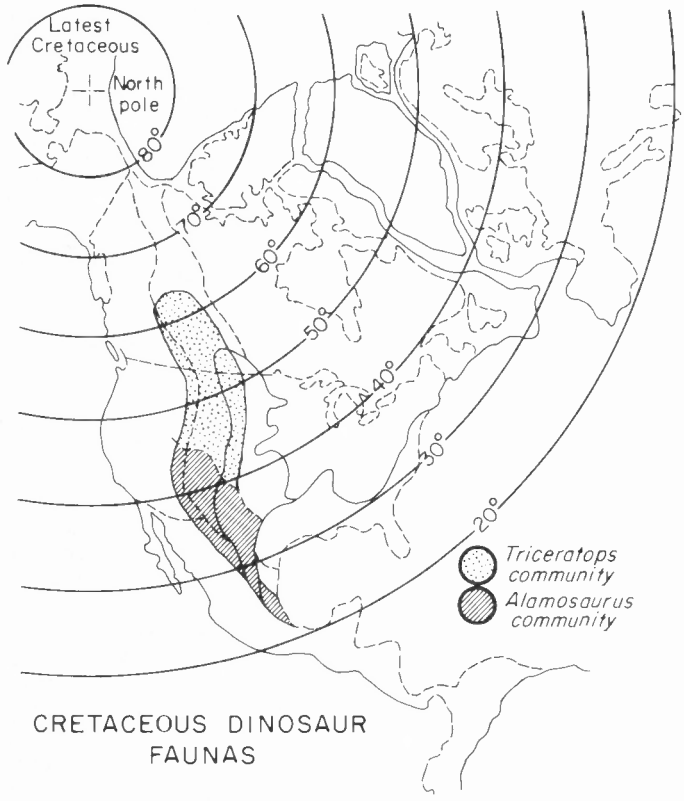


FIGURE 6—Geographic distribution of latest Cretaceous dinosaur communities in North America (after Sloan 1970).

INTERPRETATION OF THE FAUNAL DICHOTOMY

The archaic character of the southern community was touched upon by Lehman (1981). Sloan (1970) suggested that the Maastrichtian taxon, *Alamosaurus*, must have reached the southern realm by either crossing Tethys from South America or migrating along the north shore of Tethys from Europe. This hypothesis is interesting and would explain the appearance of a more "modern" taxon such as *Alamosaurus* in an archaic Campanian fauna that survived into the Maastrichtian. However, additional complications exist which also must be explained. *Pentaceratops*, another ceratopsian with a fenestrate frill, survives into the Maastrichtian Naashoibito Member, but appears to be restricted to the San Juan Basin. It is difficult to understand why *Alamosaurus* could migrate into the Big Bend, south-central New Mexico, northwest New Mexico, and Utah, while *Pentaceratops* was restricted to northwestern New Mexico. Sloan (1970) reported that *Alamosaurus* may have even gotten into the type Lance Formation of Wyoming, based on a specimen in the collections of Amherst College. Similarly, *Tyrannosaurus rex* was able to migrate into the southern community from the north, while the solid-frilled *Triceratops* could not.

Obviously, factors such as climatic and vegetational zonation may have controlled the distribution of dinosaur taxa. Competitive exclusion of taxa similarly adapted must have been operative during the Maastrichtian as it is today. Finally, our understanding of faunal complexity through time is incomplete and we simply do not have complete enough sequences as yet. However, from areas with reasonably complete faunas through time it is apparent that *Alamosaurus* is a Maastrichtian arrival; archaic faunas survive in the south; and a northern–southern faunal dichotomy in terrestrial communities exists. Some sort of filter is implied that determined which faunal elements could migrate into or out of any particular province.

Molenaar (1983) reviewed depositional cycles in the southern Colorado Plateau region. As shown by Molenaar, the last transgression affecting the Truth or Consequences area is the T-2 transgression, an early late Turonian event. By early Coniacian time the seaway had retreated (the R-2 regression) to east of Carrizozo (Fig. 7). Interestingly, Wallin (1983) reported *Lopha sannionis* from the Gallup Sandstone in the Mescal Canyon area, a species shown by Hook & Cobban (1981) to range from late Turonian to early Coniacian. In the Truth or Consequences area, the Gallup is separated from the McRae Formation by at least 700 m of strata of the Crevasse Canyon Formation (Wallin 1983). Tschudy (1976) showed that the Crevasse Canyon in the San Juan Basin contains early Coniacian pollen and may extend into the mid-Santonian (Molenaar 1983). However, the T-4 transgression of Molenaar (1983), which terminates Crevasse Canyon deposition in the San Juan Basin, did not reach Sierra County, and the region was effectively available for habitation by terrestrial faunas through McRae time (Fig. 8). Unfortunately, no information is available regarding terrestrial faunas in the region from the Crevasse Canyon, but "windows" for colonization from or to the north existed during the R-2 early Coniacian regression, the R-3 late early–middle Santonian regression, and, easiest of all, during the late early Campanian R-4 and Maastrichtian R-5 regressions.

At any point in time, faunal migration was constrained by shorelines to the north and east, while to the south Enos (1983) showed that infusions of new taxa were unlikely until the Campanian–Maastrichtian. The southern terrestrial community would thus have tended to retain an archaic character, not easily modified by the influx of more modern faunal elements such as *Alamosaurus* or *Tyrannosaurus* until the R-4 or R-5 regressions of Molenaar (1983). This modernization by introduction must have occurred later than the T-5 middle late Campanian transgression and before the R-5 regression. *Tyrannosaurus rex* appears to be present in Campanian Mesa Verde strata in Colorado (P. Robinson oral comm.), but does not reach the San Juan Basin until the Maastrichtian Naashoibito was deposited. Thus *T. rex* appears to have moved

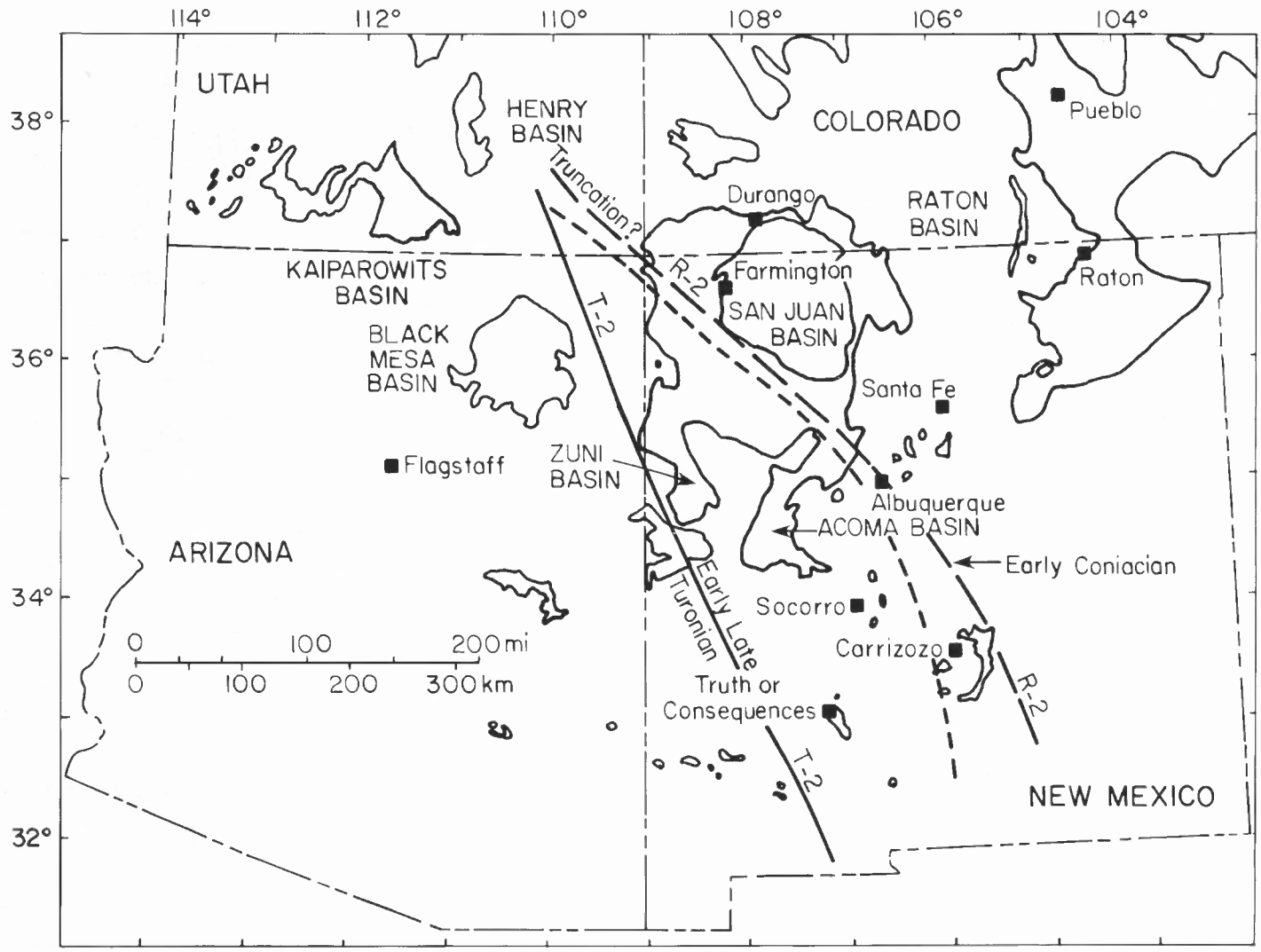


FIGURE 7—Restored position of early late Turonian shoreline at maximum T-2 transgression and early Coniacian shoreline at R-2 regression. Short dashed line indicates extent of subaerial-plain deposits associated with the regression (modified from Molenaar 1983: fig. 8).

south into south-central New Mexico and then southeast into southwestern Texas.

At the same time, *Alamosaurus* would have been advancing northwestward from the Big Bend into south-central New Mexico and then into northwestern New Mexico and Utah. The preservation of the archaic character of the southern *Alamosaurus* community is thus the product of a long period of geographic isolation. When the opportunity for modernization finally occurred, it took place in a limited fashion through the introduction of very few modern elements which were absorbed into the community structure with no apparent loss of archaic elements. Indeed, it is possible that the fenestrate ceratopsian *Torosaurus* may have been added to the *Triceratops* community from the *Alamosaurus* community. Further modernization of the *Alamosaurus* community, or transfer of additional faunal elements between both communities, was most likely forestalled by the extinction of the dinosaurs. Similarly, this extinction in turn helps to explain the distinctiveness of the faunas once the opportunity for faunal interaction was established by withdrawal of the epicontinental seaway.

It is difficult to understand, however, the complete lack of dinosaur faunas in the Raton Basin. The area must certainly have been available for colonization during the R-5 regression from either northwestern or south-central New Mexico core areas. There is no indication that suitable habitats were lacking. We suggest the possibility that dinosaur extinction in northwestern and south-central New Mexico had already begun by the time that access to the Raton Basin region became available. By the time these faunas could reach northeastern New Mexico, extinction had already overtaken them. If this is the case, the implication arises that the *Triceratops* community was able to persist longer to the north.

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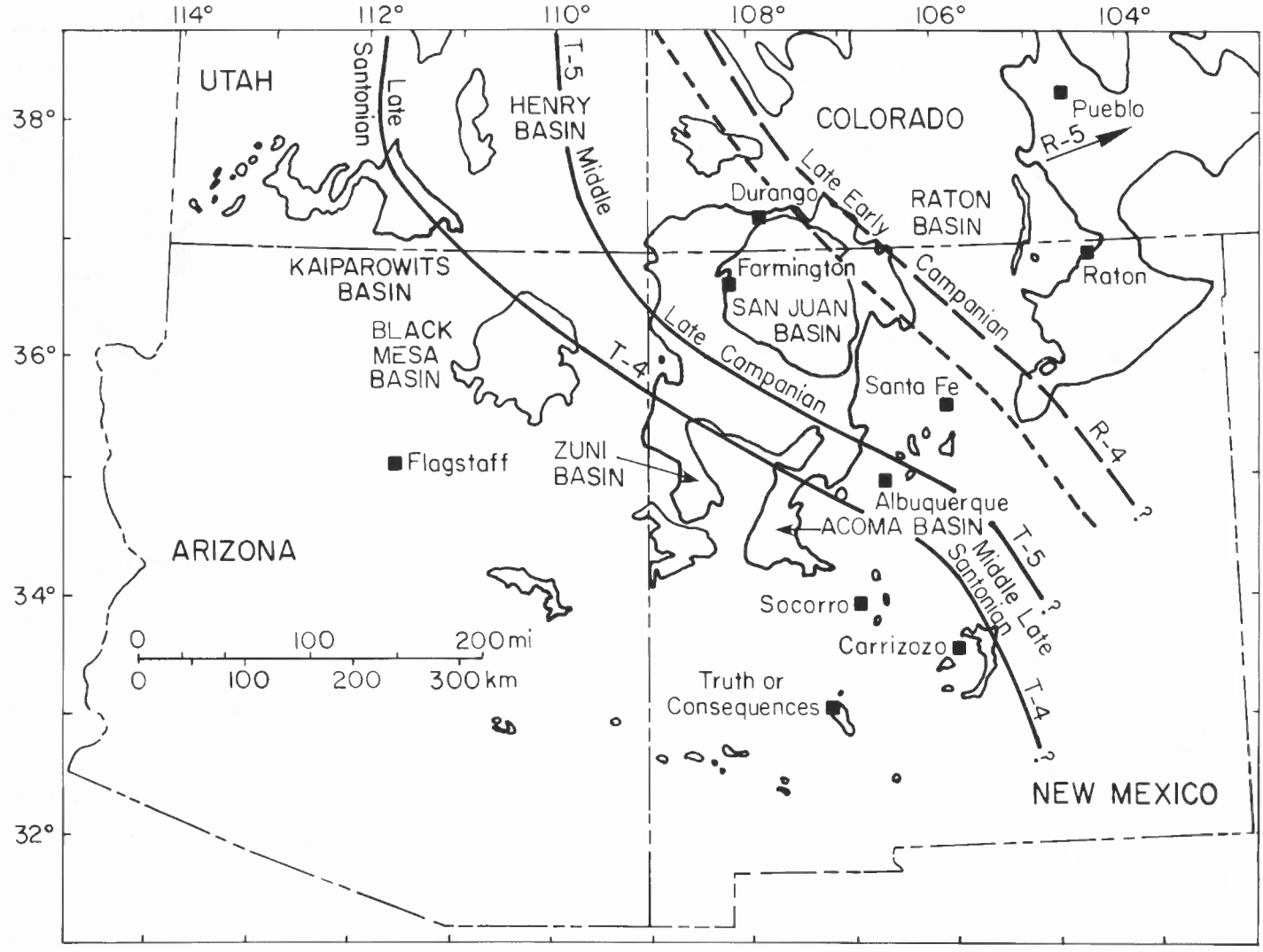


FIGURE 8—Restored positions of shorelines during middle late Santonian–Maastrichtian transgressive and regressive cycles (modified from Molenaar 1983: fig. 10).

REFERENCES

Bushnell H.P. 1953. Geology of the McRae Canyon area, Sierra County, New Mexico (M.S. thesis).—University of New Mexico, Albuquerque, 106 pp.

Bushnell H.P. 1955. Stratigraphy of the McRae Formation.—Compass, 33: 9–17.

Doyle J.C. 1951. Geology of the northern Caballo Mountains, Sierra County, New Mexico (M.S. thesis).—New Mexico Institute of Mining & Technology, Socorro, 51 pp.

Enos P. 1983. Late Mesozoic paleogeography of Mexico. *In* Mesozoic paleogeography of the west-central United States.—Society of Economic Paleontologists & Mineralogists, Rocky Mountain Section, pp. 133–157.

Gillette D.D., Wolberg D.L. & Hunt A.P. 1986. *Tyrannosaurus rex* from the McRae Formation (Lancian, Upper Cretaceous), Elephant Butte Reservoir, Sierra County, New Mexico.—This guidebook.

Gilmore C.W. 1922. A new sauropod dinosaur from the Ojo Alamo Formation of New Mexico.—Smithsonian Miscellaneous Collections, 72(14): 1–9.

Gilmore C.W. 1946. Reptilian fauna of the North Horn Formation of Central Utah.—U.S. Geological Survey, Professional Paper 210-C: 29–53.

Hook S.C. & Cobban W.A. 1981. *Lopha sannionis*—common Upper Cretaceous guide fossil in New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Annual Report for 1979–1980: 52–56.

Kelley V.C. & Silver C. 1952. Geology of the Caballo Mountains.—University of New Mexico, Publications in Geology, no. 4: 286 pp.

Lawson D. 1976. *Tyrannosaurus* and *Torosaurus*, Maastrichtian dinosaurs from Trans-Pecos Texas.—Journal of Paleontology, 50: 158–164.

Lee W.T. 1905. The Engle coal field, New Mexico.—U.S. Geological Survey, Bulletin 285: 240 pp.

Lee W.T. 1907. Notes on the red beds of the Rio Grande region in central New Mexico.—Journal of Geology, 15: 52–58.

Lehman T. 1981. The Alamo Wash local fauna: a new look at the old Ojo Alamo fauna. *In* Lucas S.G. et al. (eds.), Advances in San Juan Basin paleontology.—University of New Mexico Press, Albuquerque, pp. 189–221.

Lozinsky R.P. 1982. Geology and late Cenozoic history of the Elephant Butte area, Sierra County, New Mexico (M.S. thesis).—University of New Mexico, Albuquerque, 142 pp.

Lozinsky R.P., Hunt A.P., Wolberg D.L. & Lucas S.G. 1984. Late Cretaceous (Lancian) dinosaurs from the McRae Formation, Sierra County, New Mexico.—New Mexico Geology, 6(4): 72–77.

Lull R.S. 1933. A revision of the Ceratopsia or horned dinosaurs.—Peabody Museum of Natural History, Memoirs, 3(3): 175 pp.

McCleary J.T. 1960. Geology of the northern part of the Fra Cristobal Range, Sierra and Socorro Counties, New Mexico (M.S. thesis).—University of New Mexico, Albuquerque, 59 pp.

Melvin J.W. 1963. Cretaceous stratigraphy of the Jornada del Muerto region including the geology of the Mescal Creek area (M.S. thesis).—University of New Mexico, Albuquerque, 121 pp.

Molenaar C.M. 1983. Major depositional cycles and regional correlations of Upper Cretaceous rocks, southern Colorado Plateau and adjacent areas. *In* Mesozoic paleogeography of the west-central United States.—Society of Economic Paleontologists & Mineralogists, Rocky Mountain Section, pp. 201–224.

Sloan R.E. 1970. Cretaceous and Paleocene terrestrial communities of western North America.—North American Paleontological Convention, Proceedings, pt. E: 427–453.

Thompson S. III 1961. Geology of the southern part of the Fra Cristobal Range, Sierra County, New Mexico (M.S. thesis, revised).—University of New Mexico, Albuquerque, 75 pp.

Tschudy R. 1976. Palynology of Crevasse Canyon Formation of San Juan Basin, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Circular 154: 48–55.

Wallin E.T. 1983. Stratigraphy and paleoenvironments of the Engle coal field, Sierra County, New Mexico (M.S. thesis).—New Mexico Institute of Mining & Technology, Socorro, 127 pp.