

SPECIMENS OF *GOMPHOTHERIUM* IN THE NEW MEXICO MUSEUM OF NATURAL HISTORY AND SCIENCE AND THE SPECIES-LEVEL TAXONOMY OF NORTH AMERICAN *GOMPHOTHERIUM*

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ABSTRACT: There are four identifiable specimens of *Gomphotherium* in the collections of the New Mexico Museum of Natural History and Science in Albuquerque, all collected in New Mexico. The most diagnostic specimen, NMMNH P-28972, consists of a nearly complete skull of a young adult female found in the Pojoaque Member of the Tesuque Formation (late Barstovian). NMMNH P-19204 is an incomplete skull and lower jaws of a more mature, presumably female, individual with associated left forelimb elements recovered from the Chamita Formation (Hemphillian). Both of these specimens were collected in the Española basin near Española. A third, less diagnostic specimen (NMMNH P-3694) consists of an incomplete left lower jaw of a juvenile *Gomphotherium* collected from the northern Albuquerque Basin, probably above the Zia Formation and also of probable late Barstovian age. A fourth specimen (NMMNH P-25280) is described by Morgan and Williamson elsewhere in this volume. All North American specimens of *Gomphotherium* are currently assigned to the species *G. productum*. However, the two adult specimens in the NMMNH collection are relatively small (M3 length/width <140/<80 mm) and fall within a more restricted definition of *G. productum*. Larger *Gomphotherium* collected from the Española basin possess molars up to 50% larger than *G. productum sensu stricto* and may represent a different species. The name *G. pojoaquensis* is available for this larger taxon from the Pojoaque Member, and *G. riograndensis* is available for the large Chamita Formation gomphothere.

INTRODUCTION

Gomphotheres are among the most common fossil proboscideans, known from Miocene and Pliocene sediments in Africa, Asia, Europe, and North and South America (Shoshani and Tassy, 1996). Literally dozens of specimens have been collected in New Mexico, principally from the Española basin. Cope (1875) named *Gomphotherium productum* (= *Mastodon productus*) for a mandible collected in the Española basin. Later, field parties associated with the Frick Laboratories at the American Museum of Natural History collected numerous gomphothere fossils from the Española basin over the interval 1924 to 1968, including many complete mandibles and jaws (Frick, 1926, 1933; Osborn, 1936; Galusha and Blick, 1971). Until recently, specimens of *Gomphotherium* collected in New Mexico were repositied in museums outside of the state. Three specimens collected in the 1980s, however, are in the collections of the New Mexico Museum of Natural History and Science (NMMNH). Currently, these specimens are represented by one nearly complete and one fragmentary skull, each of adults, an incomplete adult lower jaw and associated postcrania found with the fragmentary skull, a partial juvenile lower jaw, and a partial associated skeleton. All but the partial associated skeleton are described here.

The purpose of this paper is to: (1) describe three of the gomphotheres assignable to *Gomphotherium* in the collections of the NMMNH; and (2) briefly evaluate the currently favored species-level taxonomy of North American *Gomphotherium* (e.g., Tobien, 1973) as followed by most later workers, including Lambert (1996), Shoshani (1996), and Lambert and Shoshani (1998), based on insights gleaned from these specimens.

In this paper, AMNH refers to the American Museum of Natural History, New York, FAM to the Frick Collection in the American Museum of Natural History, New York, and NMMNH to the New Mexico Museum of Natural History and Science, Albuquerque.

DESCRIPTION

Three of the *Gomphotherium* specimens in the collection of the NMMNH are described here. For each specimen, a brief description of the location and stratigraphy of the locality precedes a more detailed description of the specimen's morphological features.

NMMNH P-3694

Locality and Stratigraphy

NMMNH P-3694 was collected in the early 1980s by Ron Ratkevich at NMMNH locality 388 (Fig. 1). The stratigraphic data are somewhat vague, but indicate that the specimen was found as float, probably from a sandstone bed low in the Santa Fe Group near the Zia reservation, possibly in the Zia Formation. Later work, including substantial revisions of Santa Fe Group nomenclature underway by the New Mexico Bureau of Mines and Mineral Resources, suggests that the specimen is probably much younger.

Specifically, NMMNH records indicate that P-3694 was found near Piedra Parada (Standing Rock) in the vicinity of secs. 11 and 12, T14N, R1E. We believe the specimen cannot have come from outcrops of the Zia Formation in this area, which are late Arikarean and Hemingfordian in age (Galusha, 1966). Instead,

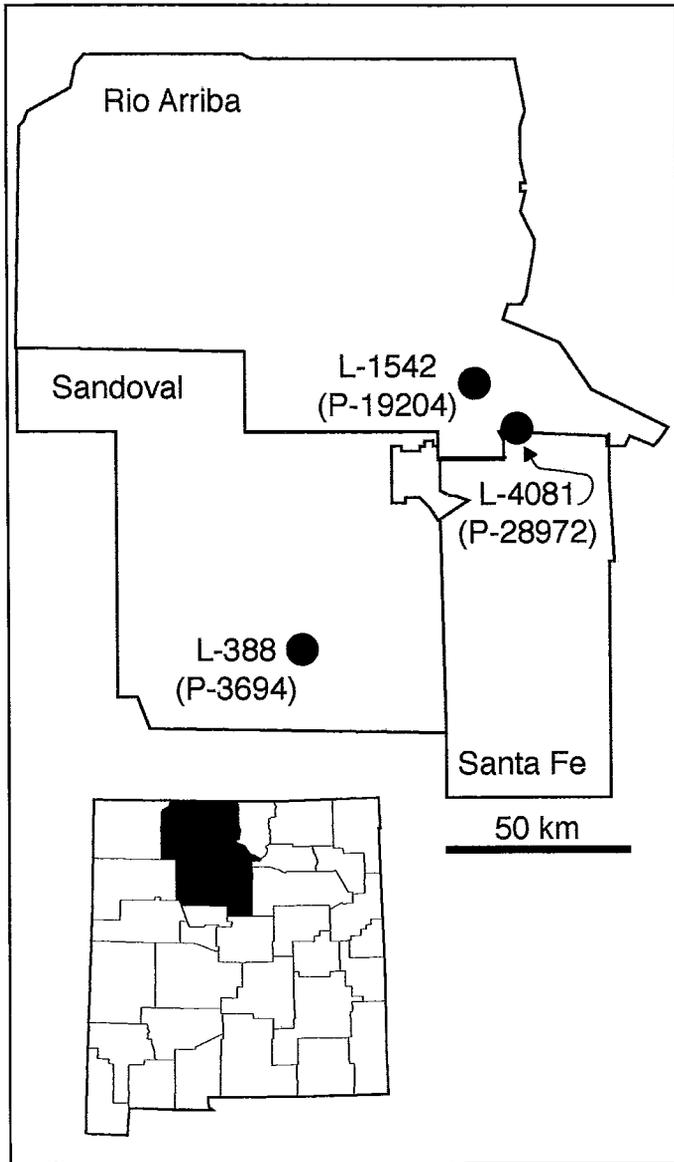


FIGURE 1. Index map showing localities of *Gomphotherium* specimens in the collection of the NMMNH.

it must have come from younger Santa Fe Group rocks, probably the Cerro Conejo Formation (stratigraphy follows Pazzaglia et al., 1999, but see Connell et al., 1999) exposed immediately east of the Jemez fault in sec. 12. The Cerro Conejo Formation is primarily of Barstovian (middle Miocene) age (Fig. 2).

Description

The only specimen assigned to NMMNH P-3694 is a well-preserved partial left jaw containing portions of the symphysis, a deciduous tooth interpreted as the left dp4, and the first molar, which is unerupted (Fig. 3A-C). This is the most complete mandible of *Gomphotherium* in the collections of the NMMNH. The specimen measures approximately 450 mm in length and preserves most of the symphyseal region, most of the tooth row, and a nearly intact coronoid process. The preserved portion of the symphyseal region is short (75 mm), precluding assignment to the amebelodont or "shovel tusked" gomphotheres. The coronoid

process is broad in lateral view, approximately one-third the length of the jaw, and is as much as 190 mm tall.

Dentition associated with P-3694 includes the alveolus for the dp3, a worn dp4, and an unerupted m1 (Table 1). The alveoli for the dp3 are not yet resorbed, and the condition of the specimen suggests that a posterior fragment of this tooth may still have been in use, falling out only after the animal died. The dp4 and the m1 are posterior to these alveoli. Both teeth are trilophodont and bunodont. Preparation carried out under the direction of Dave

Epoch		LMA	Albuquerque Basin		Española Basin	
Pliocene	early	Blancan	Santa Fe Group	Arroyo Ojito Formation	Ceja Member	Puyé Formation
	5.3 Ma					Hemphillian
Miocene	late	Clarendonian		Navajo Draw Member	L-1542	
	11.2 Ma				Barstovian	Cerro Conejo Formation
middle	16.6 Ma	Hemingfordian	Zia Formation	Chamisa Mesa Member		
	early				Arik.	Piedra Parada
				Nambé Member		

FIGURE 2. Stratigraphy of localities of *Gomphotherium* specimens in the collection of the NMMNH. Albuquerque basin stratigraphy simplified from Connell et al. (1999) and Pazzaglia et al. (1999). Española basin stratigraphy simplified from Tedford and Barghoorn (1993).

TABLE 1: Measurements of *Gomphotherium* teeth in the collections of the NMMNH

Table 1a: NMMNH P-3694

tooth	length	width
left dp4	75	38
left m1*	102	38

* tooth is not erupted, and width is not readily measured.

Table 1b: NMMNH P-19204

tooth	height	width	tooth	length	width
RI2 (tusk)	?	47+	RM2	111*	75*
LI2 (tusk)	72	61*	LM2	113	72+
Ri2 (tusk)	49	38	RM3	140*	60*
Li2 (tusk)	50	37	LM3	141	77
			Rm2	92*?	51
			Lm2	77+(roots)	39+(roots)
			Rm3	110*?	75*?
			Lm3	150	75

* measurement affected by breakage

+ measurement affected by wear

? measurement affected by matrix obscuring tooth dimensions

(roots) measurement at roots, crown destroyed

Table 1c: NMMNH P-28972

tooth	height ¹	width ¹	length	Tooth	length	width
RI2 (tusk)	51/39	38/17	195	RM2	103	61
LI2 (tusk)	48/23	36/16	170	LM2	106	64
				RM3	128?	70
				LM3	137	69

¹ Measured at the premaxilla/1 cm from tip

? tooth incompletely erupted, affecting measurement

For all tables:

All measurements in mm.

Lengths measured at greatest dimension.

Widths measured across the second loph, which is generally the greatest dimension.

Height of incisors measured at greatest vertical dimension.

Width of incisors measured perpendicular to height.

Gillette exposed the roots of the dp4 and the crown and roots of the m1 (Fig. 3A). The dp4 is extensively worn (Fig. 3C), with dentine exposed on all three lophids. Wear is greatest on the labial portions of the lophids. Prominent pretrite and posttrite trefoils are present, although these too are worn. There is a small conule at the posterior margin of the tooth. The enamel is broken on the labial margin, rendering determination of the presence, size, and shape of a cingulum impossible.

In life, the m1 was probably unerupted, although the first two loph project above the bone surface. The three primary lophids are complex, with numerous cuspids, including extensive, complex posttrite trefoils projecting posterolingually from the labial margins of the first two lophids. A small, auxiliary conule is present at the posterior margin of the tooth, but this is clearly not an incipient fourth lophid. Thus, we interpret this tooth as the m1 based on its trilophodont morphology and significantly larger size than the dp4 (Table 1). Because the tooth is essentially

imbedded in the coronoid process, determination of the presence, size, and shape of a labial cingulum is impossible.

Using the dental ages developed by Tassy (1996), this animal is probably in dental stage VI. This determination is based on the loss and impending resorption of all deciduous teeth anterior to dp4, the extensively worn lophids on the dp4, and the unerupted m1.

NMMNH P-19204

Locality and Stratigraphy

NMMNH P-19204 was collected in the mid-1980s by then-NMMNH curator Dave Gillette from NMMNH locality 1542. This locality is approximately 1 km north and east of Chamita in Arroyo de la Mesita. Galusha and Blick (1971) map this area as entirely within the Chamita Formation. MacFadden (1977) indicated a Hemphillian (latest Miocene-Pliocene) age for the Chamita Formation, based on mammalian biochronology, radioisotopic dates,

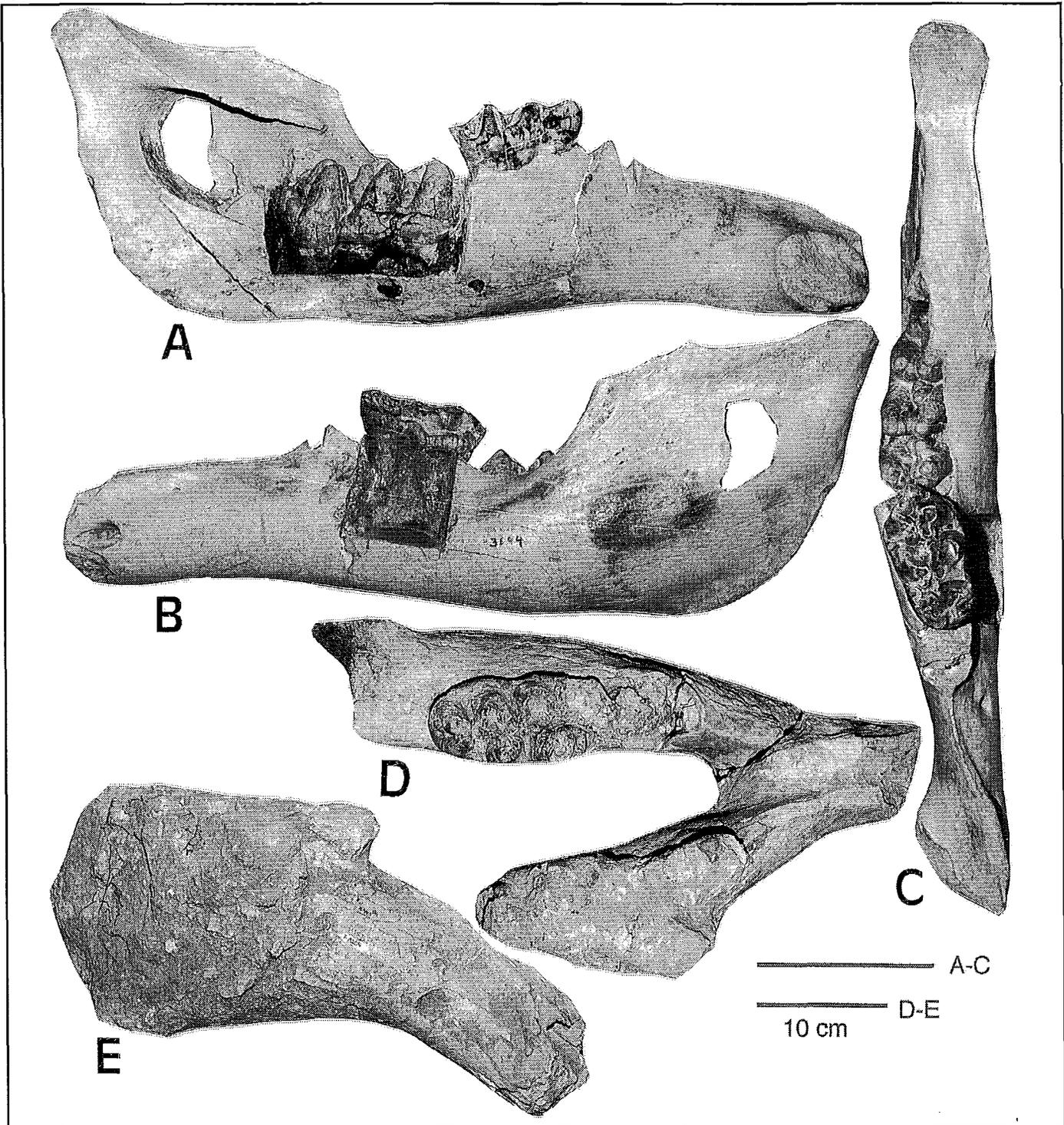


FIGURE 3. Photographs of *Gomphotherium* in the collection of the NMMNH. A-C, NMMNH P-3694, partial left jaw in medial (A), lateral (B), and occlusal (C) views; D-E, NMMNH P-19204, incomplete mandible in occlusal (D), and right lateral (E) views.

and magnetostratigraphy. This makes P-29872 the youngest specimen of *Gomphotherium* in the collections of the NMMNH.

Description

NMMNH P-19204 consists of a partial skull and lower jaws as well as associated forelimb elements. The specimen is not fully prepared, and the incomplete skull remains partially encased in

the field jacket. The lower jaw (Fig. 3 D-E) requires assembly, but includes broken tusks, fragmentary right molars, left m2, and the moderately well preserved left m3. The only identifiable postcrania are the proximal ends of the associated left ulna and radius.

The skull can only be viewed in ventral and left lateral aspects in the present state of preparation (Fig. 4D-E). Although sutures are partially obscured by crushing, distortion, and ma-

trix, portions of the left premaxilla, maxilla, lachrymal, and frontal are preserved, as may be portions of the left parietal and squamosal. The existing portions of the frontal are only visible in lateral view, but do not appear to be domed, as in male elephants, indicating that the specimen may be a female. The zygomatic arch is broken anterior to the malar (jugal). In ventral view, the midline suture separating right and left premaxillae, maxillae, and palatines is readily traced from the tusks posteriorly to the anterior margin of the interior nares, where the specimen is broken.

The specimen was probably found lying on its left side, as the left teeth are much better preserved than the right. Both M2s and M3s are present and bunodont. The M2s are trilophodont, and the M3s are tetralophodont. The right molars are broken, but the left molars are demonstrably more worn, particularly the left M2, which has no enamel preserved on the lingual surface. The right M2, although shattered, does preserve a nearly complete ring of enamel on the lingual surfaces.

The left M3 is slightly worn anteriorly but otherwise complete. It preserves four distinct lophs, the first and second of which are slightly worn, with the greatest wear on the medial surfaces, where significant amounts of dentine are exposed. The third and fourth lophs are unworn. A prominent cingulum is present from the anteromedial corner of the first loph posterior to the middle of the third loph. Prominent, paired secondary trefoils are present in the interlophs. These pairs typically consist of a smaller posttrite trefoil anterior to a larger pretrite trefoil. The first pretrite trefoil is worn to the dentine; the other trefoils are unworn. There may be some incipient cementum deposited in the interlophs medial to the trefoils.

The lower jaw of P-19204 is incomplete but preserves most of the symphysis, portions of the incisors, portions of both m2s and m3s, and part of the left coronoid process. As preserved, the symphysis is approximately 160 mm long, and the tusks are in contact medially at the broken anterior margin. In cross-section, the tusks are slightly beveled medially, so that the dorsal surface is concave in anterior aspect. This is a feature characteristic of amebelodont gomphotheres, but the symphysis is too short to assign to any amebelodont taxa. Further, the lower tusks are dorsoventrally tall, not compressed as in the amebelodonts.

The right m2 and m3, although present, are badly preserved and obscured by matrix. The left m2 is broken at the roots. The left m3 is comparatively well preserved, except for the worn and broken first loph. All four lophs show some wear, with the greatest wear on the labial surfaces. The first lophid, although broken, also was clearly worn through the enamel anteriorly. The second lophid is also badly worn. The third lophid shows little dentine on the lingual cusp, but much greater wear on the labial portion of the lophid. The fourth lophid shows some wear on the labial portion of the lophid. A prominent cingulid is present along the lingual surface from at least the first interlophid, posteriorly to the fourth lophid. The trefoils are located on the median axis of the tooth or slightly labially. The posttrite trefoils are larger than the adjoining pretrite trefoils of the next most posterior lophid. The trefoils between the second and third lophs are strongly worn and expose dentine. The next set of trefoils is far less worn, and no dentine is exposed.

Using the dental age determinations of Tassy (1996), this specimen represents an animal of dental age XX or XXI. The upper molars indicate a dental age of XIX (first two lophs of M3 worn) to XXI (M2 wear figures coalesced, resulting in an excavated tooth). The lower molars show similar wear of the m2s, but the m3 shows little excavation on the fourth lophid, and thus are representative of dental ages XX or XI. In terms of total enamel removed, the lower teeth are more worn than the uppers, as is typical of gomphotheres (Tassy, 1996). As Tassy (1996) defined only 23 (XXIII) dental ages, this animal represents an adult.

NMMNH P-28972

Locality and Stratigraphy

NMMNH P-28972 was found *in situ* low in an arroyo floor north and east of Española in Arroyo del Llano (J. Whetstone, oral comm., 1999), and this site has been designated NMMNH locality 4081. This arroyo, known as "first wash" by AMNH parties, is in the Pojoaque Member of the Tesuque Formation and has yielded extensive collections of late Barstovian (middle Miocene, approximately 14.5 Ma) mammals (Galusha and Blick, 1971; Tedford, 1981; Tedford and Barghoorn, 1993, 1997). This is the oldest confirmed age for a gomphothere in the NMMNH collections, and probably represents the same general horizon and age as the FAM gomphothere collections from the area (Galusha and Blick, 1971; Tedford and Barghoorn, 1993, 1997).

Description

NMMNH P-28972 consists of a nearly complete skull, including tusks, M2s, and M3s. The specimen was found lying on its right side, so the left side is incomplete and partially restored with plaster. The right side is exceptionally complete and even preserves the zygomatic arch. The tusks are preserved, but the right tusk is considerably more worn than the left (Fig. 1). The M2s are well worn but the M3s are neither strongly worn nor completely erupted, and they are somewhat hidden by crushing of the palate, particularly the pterygoids.

The whole skull is remarkably undistorted. The premaxillae are both complete, and only slightly displaced due to breakage and subsequent reconstruction. The right maxilla is complete, including the zygomatic process. The left maxilla is nearly complete, but heavily reconstructed in the alveolar region. Both nasals are intact, and form a bulbous projection along the posterior margin of the external nares. The right frontal is complete and intact. The left frontal is nearly complete but somewhat fragmented. The dorsal surfaces of each are essentially flat (horizontal) in lateral view. Similarly, the right parietal is complete and intact, but the left is badly damaged. Like the frontals, the dorsal surfaces of the parietals are essentially flat in lateral aspect, with only a gentle slope rising to the posterior margin of the skull. The lack of a domed skull roof is a typical feature of female adult elephants, including gomphotheres (Tassy, 1996). The right squamosal is perfectly intact, including a pristine articulation with the malar (jugal) along the posterior margin of the zygomatic arch, which it overlaps dorsally. The left squamosal is badly fragmented, and much of the posterior portion has been restored with plaster.

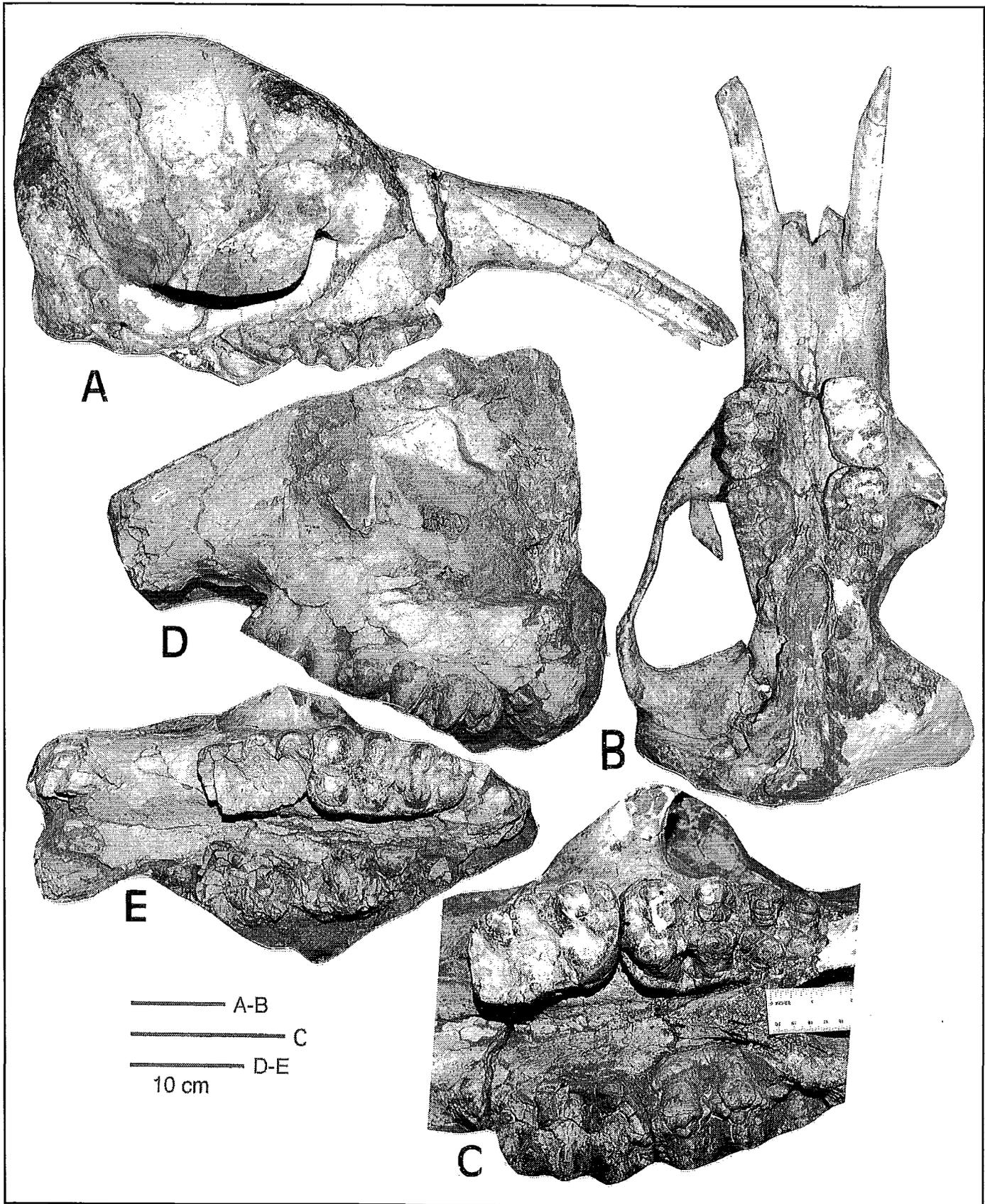


FIGURE 4. Photographs of *Gomphotherium* in the collection of the NMMNH. A-C, NMMNH P-28972, (A) nearly complete skull in right lateral view, (B) nearly complete skull in ventral view, (C), dentition in occlusal view; D-E, NMMNH P-19204, partial skull in left lateral (D), and occlusal (E) views.

The external auditory meatus is only preserved on the right side, immediately posterior to the zygomatic arch, where it remains filled with matrix. Both supraoccipitals are complete. The right exoccipital is better preserved than the left, but together they form an intact rim enclosing the nuchal fossa on the posterior surface of the skull. Beneath this hollow the foramen magnum is directed posteriorly and ventrally.

The palate is moderately well preserved, although many smaller or more delicate structures are either damaged or displaced. The medial suture separating the left and right halves of the skull is readily traced from the front of the skull posteriorly to the internal nares. Both pterygoids are slightly crushed and displaced. The right pterygoid is slightly displaced laterally, so that the largest process overhangs the right M3 in ventral view. The left pterygoid appears to be closer to its natural position, but is now crushed, broken, and restored with plaster. The deeply excavated internal nares show no trace of the medial septum formed by the vomers, which are probably buried in the sediment that fills the nares. The tympanic bullae are slightly crushed and somewhat fragmented, especially on the left side, where the bulla itself is covered in plaster. The right bulla is better preserved, and relatively small and narrow. The bulbous basioccipital is slightly fragmented but otherwise undistorted.

The dentition of NMMNH P-28972 is well preserved. Both tusks are present and essentially complete, with thin bands of enamel 17-20 mm high running down the lateral surfaces. Notably, the left tusk tapers to a sharp point approximately 195 mm anterior to the premaxilla, whereas the right tusk tapers to a blunt, worn, wedge or chisel-shaped edge approximately 170 mm anterior to the premaxilla. The tables of measurements also document the change in shape from the unworn point of the left tusk (23 mm x 16 mm 10 mm from tip) relative to the chisel-point on the right tusk (39 mm x 17 mm 10 mm from tip). This wear almost certainly indicates a preference for using the right tusk or "right tuskedness" of the animal during life. Such differential wear is not uncommon on fossil elephants.

Only the faintest depressions remain anterior to the M2s, indicating almost complete wear and subsequent resorption of the M1s and their alveoli. The M2s are well worn but clearly bunodont and trilophodont. The left M2 is more deeply worn than the right, especially lingually, and has been partially reconstructed with plaster. The right M2 is less deeply worn, but the enamel has still been worn off of all three lophs, exposing dentine. The M3s are at least partially erupted. The left M3 apparently is almost completely erupted, yet the third and fourth lophs of the right M3 remain almost completely encased in a thin sheet of bone (Fig. 4B,C). The displacement of the right pterygoid ventral and forward of its natural position furthers the impression that the right M3 is almost completely unerupted. However, a distinct wear facet is present on the first loph, indicating that the anterior margin of the right M3 was definitely in occlusion at the time the animal died. As described in the preceding section on the skull, the alveolar region of the left teeth has been extensively reconstructed, so it is possible that the left M3 was no more erupted than the right, as only the first two lophs show significant wear. Both M3s possess a prominent lingual cingulum that runs the length of the exposed tooth. Posttrite and pretrite trefoils are present between

each pair of lophs on the left M3. These are generally situated near the lingual margin of the tooth, but are deflected slightly labially to form "v-shaped" auxiliary chewing surfaces.

Based on the dental ages of Tassy (1996), NMMNH P-29872 probably represents an individual of dental age XVII or XVIII. This is based on the total resorption of M1, extensive wear on the M2, and the incipient wear facets on the anterior lophs of M3. Thus, this specimen represents a young adult, almost certainly a female, and not as mature as the individual represented by NMMNH P-19204.

SPECIES-LEVEL TAXONOMY OF *GOMPHOTHERIUM*

Gomphotherium was first described by Burmeister in 1837 (Lambert, 1996; Shoshani, 1996). Since that time a bewildering array of generic and specific names have been applied to specimens now considered congeneric with *Gomphotherium* (see Shoshani, 1996, appendix A, for a comprehensive review). Later, Cope (1875) named the first gomphothere discovered in New Mexico, *Mastodon productus*, and Frick (1926, 1933) and Osborn (1936) applied numerous additional names, including *Trilophodon*, *Serridentinus*, and *Ojocalientinus*, all to gomphotheres found in the Española basin. Later workers, such as Tobien (1973) and Shoshani (1996), synonymized most of these taxa with *Gomphotherium*, and Tobien (1973) went so far as to synonymize all five species of *Gomphotherium* from the Española basin into *G. productum*. There is little reason to question the work of Tobien (1973) at the generic level (e.g., Shoshani, 1996). Shoshani (1996) did not address species-level taxonomy of *Gomphotherium*. All current workers agree that *Gomphotherium* in general and North American *Gomphotherium* in particular require revision (Lambert, 1996; Shoshani, 1996; Lambert and Shoshani, 1998). The range of variation in both size and morphology of gomphothere specimens from the Española basin (Frick, 1926, 1933) also casts doubts on Tobien's (1973) conclusions at the species-level. Consequently, the following discussion regarding the species-level taxonomy of gomphotheres from the Española basin is presented to the extent that it is conclusive for the NMMNH specimens.

The NMMNH specimens described here clearly pertain to *Gomphotherium*, based on the presence of bunodont trilophodont molars, prominent cingula, primary trefoils, and enamel bands on the lateral surface of the tusks. Although not all of these features can be observed in P-3694, it is noteworthy that this specimen is: (1) clearly a bunodont trilophodont proboscidean, and (2) cannot be a shovel-tusked taxon, based on the short dentary symphysis.

The adult specimens are complete enough to merit further taxonomic consideration. According to Tobien (1973), both should be referred to *G. productum*. However, if size of the specimens (based on third molar dimensions) is considered, then both NMMNH specimens would plot at the lower end of the size range for the Santa Fe Group gomphotheres plotted by Tobien (1973:fig. 9). Furthermore, large gomphotheres from the Santa Fe Group have third molars up to 50 percent larger than those of the NMMNH specimens (Tobien, 1973; see also Frick, 1926, pp. 156-157). Tassy (1996) reported strong sexual dimorphism in a population of *G. angustidens* from En Pejouan (Miocene of France), but even this

dimorphic population only achieved roughly 40% divergence in M3 and m3 size between the largest adult males and the smallest adult females. Thus, it seems likely that there is more than one species of *Gomphotherium* in the Santa Fe Group. The oldest named applied to the specimens of the larger species from within the basin is *G. pojoaquensis* (Frick), but this may not be the oldest name available for the larger taxon.

Therefore, based on size alone, both P-19204 and P-29872 could be assigned to *G. productum*, the type of which is a relatively small mandible from approximately the same horizon as P-29872 (Tobien, 1973). However, the dentition of P-19204, with its more complex trefoils, is clearly more advanced than that of P-29872, and the specimen itself may be as much as 10 million years younger. Although age is not a suitable diagnostic character, the combination of the derived dentition seen in P-19204 and its younger age suggest that perhaps this specimen may represent a different species. However, determining this for certain would require, at the least, a systematic study of all North American gomphotheres. Interestingly, Tobien (1973, p. 223) notes that another, large gomphother is also present in the Chamita Formation. This taxon, if valid, might be termed *G. riograndensis* (Frick), and the smaller taxon represented by P-19204 may represent a smaller taxon not previously reported from the Española basin.

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