56,9,61E:14,31,4

ARTICLE II — TOOTH SEQUENCE IN CERTAIN TRILOPHODONT TETRABELODONT MASTODONS

and

TRILOPHODON (SERRIDENTINUS)[1] *POJOAQUENSIS*, NEW SPECIES

By Childs Frick

CONTENTS

INTRODUCTION

A tendency to extraordinary enlargement of the posterior molars at the expense of the more anterior teeth pervades the Proboscidea. The present paper discusses two resulting and extremely different types of tooth sequence and their bearing on tooth homology and the peculiar problem of tooth succession in this order. These types are exampled in two trilophodont forms secured during the course of the author's investigation of the Miocene deposits of Santa Fé, New Mexico[2] and the Pliocene deposit of the Eden, California.[3] The paper further describes a new species of American trilophodont based on remains of great size

[1] The revised generic names adopted in Professor Osborn's forthcoming Memoir on the Proboscidea are given in parentheses throughout this paper in which the former generic nomenclature of the mastodonts is used.
[2] Frick, Childs, 1926, Bull. Amer. Mus. Nat. Hist., LVI, Art. I.
[3] Frick, Childs, 1921, Univ. Cal. Pub. Dept. Geol. XII, p. 405, Figs. 159–165, and Pl. L.

occurring among the rich series from the former horizon, and a very remarkably preserved skull (Fig. 1A) here considered as representing a paratype of this species.

Falconer[1] has well remarked that ". . . hardly any two [palæontologists][2] concur respecting the number, form, and succession of the teeth in the different species of mastodon and elephant . . . [as] a limited number only of the whole [tooth] series can be met with in any one fossil specimen, even under the most favorable conditions . . . [because of] the peculiar mode of succession of the molar teeth . . . by repeated renewals from back to front . . . as the worn and exhausted grinders drop out . . .; [and that] it is this peculiarity which has so long retarded the attainment of the accurate knowledge of the dentitions of the living species." A fertile field still awaits the investigator, for not only may the knowledge of the status of reduction in the tooth-series of different species or genera be of importance in the verification of hypothetical phylæ (as the *Phiomia-Trilophodon*), but an understanding of the morphology of the premolars themselves may aid in the solution of taxonomic problems (as exampled in the widely different p^4's of *T.* (*S.*) *productus*, (?) *T. turicensis*, and (?) *T.* (*S.*) *leidii*). Unfortunately, a thorough and general comparison of the true premolar teeth of representative mastodon types cannot yet be attempted because of the absence of sufficient representative material. Much, however, may be done toward the correct assignment to their true position in the series of such premolars as are present in our collections, and the comparison of homologous specimens from different horizons.

The first of the two types of tooth sequence here described is that displayed in a collection of specimens of widely differing size from the Santa Fé Miocene of New Mexico, referred to *Trilophodon* Falconer (*Serridentinus* Osborn). The new material includes various series exhibiting the deciduous, the replacement and the permanent teeth *in situ*, and affords the first definite knowledge of the immature dentition and tooth sequence in this form.

The second of the two types of tooth replacement here discussed is represented by undescribed jaws from the Eden Pliocene, which are tentatively grouped with certain previously described Eden specimens, and as a separate species provisionally placed near those forms typified by the Cope deflected-beaked Blanco mandible, referred by Osborn to the genus (?) *Rhynchotherium* Falconer.[3] In great contrast to the former

[1] Falconer, 1868, Palæontological Memoirs, I, p. 45.
[2] Bracketed [ ] portions throughout this paper supplied by present author.
[3] Osborn, H. F., 1921, Amer. Mus. Novit., No. 1, p. 6.

four-tusked, long-symphysised types, in this four-tusked, short-jawed species, the anterior juvenile teeth have no vertical successors, and are crowded out directly from back to front by the molars.

The Santa Fé collection includes, as above remarked, specimens that add largely to our previous knowledge of the adult characters of *T.* (*S.*) *productus* Cope, and certain other remains of large size and distinct proportions that witness the occurrence of a second species. I call the latter *T.* (*S.*) *pojoaquensis* in honor of the pueblo of the locality, and refer to it as paratypes the unusually well-preserved skull and the mandible of Figs. 1A and B.

ACKNOWLEDGMENTS.—The new material here described was collected by Mr. Joseph Rak during the course of the writer's investigation of the Miocene deposit of Santa Fé, New Mexico,[1] and the Pliocene deposit of Eden, southern California,[2] with the exception of the maxillary specimen taken as the type of the new species, *T.* (*S.*) *pojoaquensis*, which was collected at Santa Fé by Messrs. Simpson and Falkenbach. Through the generous coöperation of Dr. Gidley and the authorities of the National Museum, I have been able to study and partially refigure the fragmental maxillary specimen from Santa Fé referred by Cope to *T.* (*S.*) *productus*, and the unique immature maxillary specimen from Florida referred by Leidy to *T.* (*S.*) *floridanus*, and here taken as the type of the new species, (?) *T. leidii*. Prof. Osborn, to whom I am ever indebted for much goodly advice, has very kindly read the article in manuscript and has permitted the inclusion in parentheses of the revised generic names which are to be used in his great forthcoming memoir on the Proboscidea. The new material was prepared and sectioned by Messrs. Charles Christman and Charles Falkenbach of the American Museum. The drawings and diagrams have been executed by Miss H. de Berard.

HISTORICAL

The splendid plates of Lartet, von Meyer, Falconer, Leidy, Andrews, and Schlesinger[3] illustrate various stages of tooth sequence in the Proboscidea of Europe, Asia and America.

Falconer[4] remarks that Bronn, as early as 1838, in 'Lethæa Geog-

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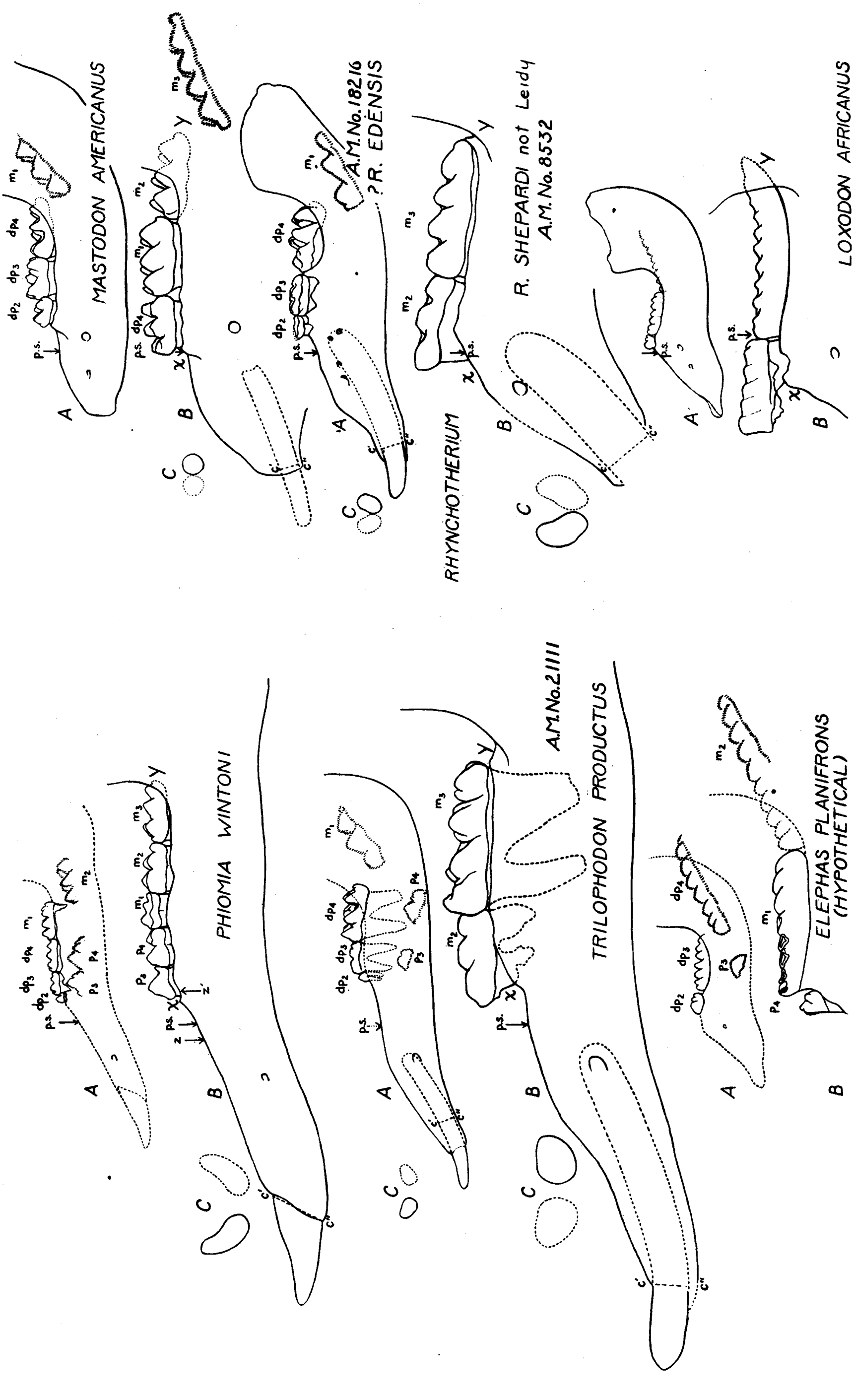
[1] Frick, C., 1926, Bull. Amer. Mus. Nat. Hist., LVI, Art. I.
[2] Frick, C., 1921, Univ. Cal. Pub. Dept. Geol., XII, No. 5, p. 339.
[3] Lartet, 1859, Bull. Soc. Geol. Fr. (2) XVI, Pl. XIV. Von Meyer, H., 1867, Palæontographica, XVII, Pl. III. Falconer, *loc. cit.* Leidy, 1896, Trans. Wagner Free Inst. of Sci., IV, Pl. IV. Andrews, 1906, Catalogue of the Tertiary Vertebrata of the Fayûm, Egypt, Pl. XVIII; 1908, Philos. Trans. R. Soc. of London, (B) CXCIX, Pls. XXXI and XXXII. Schlesinger, 1917, Denkschriften, K. K. Naturhist. Hofmuseums, I, Pls. II, III, IV, etc.
[4] Falconer, 1868, Palæontological Memoirs, II, pp. 6 and 38.


MASTODON AMERICANUS
A.M.No.18216
?R. EDENSIS
RHYNCHOTHERIUM
R. SHEPARDI not Leidy
A.M.No.8532
LOXODON AFRICANUS
PHIOMIA WINTONI
A.M.No.21111
TRILOPHODON PRODUCTUS
ELEPHAS PLANIFRONS
(HYPOTHETICAL)

nostica' stated that the mastodon is characterized among other characters by molars which are replaced from back to front, excepting the most anterior one or more milk molars, while in the elephant all the molars are replaced in a horizontal direction; and that Owen a year later noted that in certain mastodons the last milk molar was displaced by a vertical successor or premolar (correcting a previous statement that when a single premolar is developed it is the successor to the penultimate milk molar).

Lartet, in 1859, figures (Pl. XIV) under *M. angustidens* Cuvier, according to their proper sequence, unassociated teeth of upper and lower dentitions from Simorre, representing individuals of variable size. He designates the three antero-most teeth of the jaw as the "first to third milk teeth [$dp\frac{2}{2}$–$dp\frac{4}{4}$];" shows that the last two of these are replaced by premolars of relatively simple construction which he designates as "the first and second premolars [$p\frac{3}{3}$–$p\frac{4}{4}$];" remarks that the first upper molar is in use before the eruption of the two premolars, that the less worn condition of the "first milk tooth" proves it to erupt after the "second milk tooth," and that the "first milk tooth" of the lower jaw never has a vertical successor. Lartet thus concludes that in the mastodons generally [mastodons such as *M. americanus* evidently not considered] as in *Dinotherium*, the second [$dp\frac{3}{3}$] and third [$dp\frac{4}{4}$] milk molars of both jaws are each replaced by premolars of relatively simpler construction, but that the first milk molar [$dp\frac{2}{2}$] is without a successor. His figures include an immature mandible (Pl. XIV, Fig. 4) with trace of the alveolus of dp_2, the dp_3, dp_4, m_1 and p_3–p_4 in germ; and a maxillary specimen (Fig. 3) with p^3, p^4, m^1 (worn) and m^2. He also figures the

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Fig. 1C. A diagrammatic representation of tooth succession in six proboscidean genera.

The figures are scaled so that in the mature jaws (B) the approximate greatest anteroposterior alveolar distance (xy) occupied by teeth at one time is brought to unity. The scale of the immature jaw (A) is in each figure approximately that of the mature jaw (B). The figures are aligned on posterior border of symphysis (p. s.). C = cross-section of inferior tusks at c′c″.

Phiomia (*Palæomastodon*) *wintoni* Andrews. Fayûm Oligocene. After Andrews (1908, Pl. XXXI, Fig. 2, and Pl. XXXII, Fig. 2).

Trilophodon (*Serridentinus*) *productus* Cope. (A) Hypothetical, based on Amer. Mus. 21113 and 21112. (B) Amer. Mus. 21111. Santa Fé Miocene, New Mexico.

Elephas (*Archidiskodon*) *planifrons* Falconer and Cautley. Hypothetical, based on Falconer's figures ('Fauna Antiqua Sivalensis,' Pl. XII, Figs. 8 and 9, 10 and 11; and Pl. X, Fig. 10).

Mastodon americanus Kerr. After Warren figures, and casts Amer. Mus. Coll.

Rhynchotherium. (A) (?) *R.* (*Dibelodon*) *edensis* Frick. Amer. Mus. 18216. Eden Pliocene. (B) "*R. shepardi* (not Leidy)" Cope. Amer. Mus. 8532. Blanco, Texas.

Loxodon africanus Blumenbach (*Loxodonta africana*). Amer. Mus. specimens.

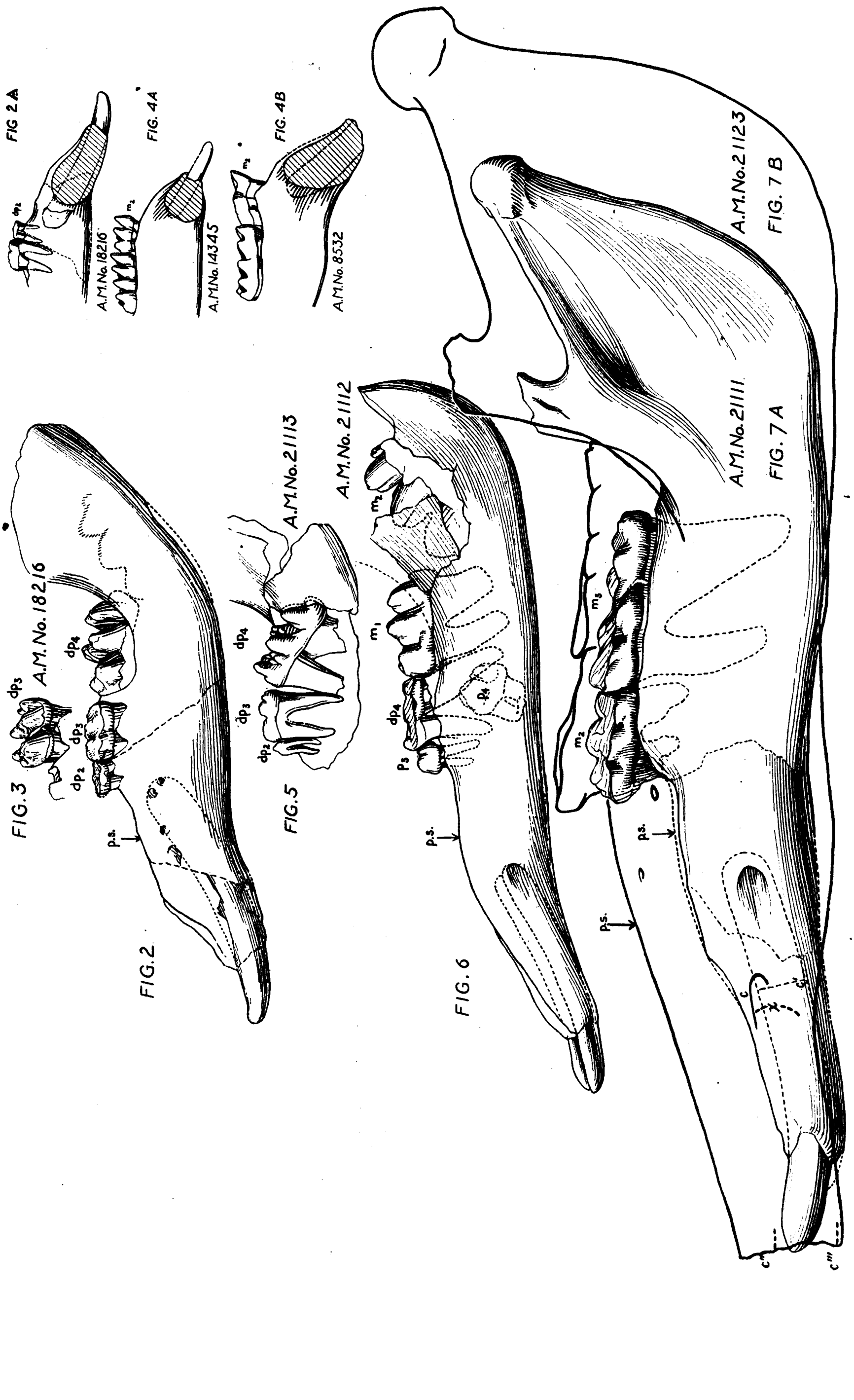


FIG 2 A
A.M.No.18216
FIG. 4A
A.M.No.14345
FIG. 4B
A.M.No.8532
FIG. 3
A.M.No.18216
FIG. 2
FIG. 5
A.M.No.21113
A.M.No.21112
FIG. 6
A.M.No.21111
FIG. 7 A
A.M.No.21123
FIG. 7 B

second and third milk teeth of *T. longirostris* (Fig. 5) as replaced by premolars, the second premolar being four- instead of three-crested.

Falconer in 1868[1] demonstrates (in the case of specimens referred to *E.* (*Archidiskodon*) *planifrons*, which prove the two posterior of the three anterior teeth to have successors) the correctness of Owen's hypothesis "that the three first developed molars are analogous to the true deciduous molars of ordinary Pachyderms;" and holds "that when a single premolar is developed it is the successor to the last milk molar . . . [that] the penultimate premolar replaces only the corresponding milk molar . . . [that] the antepenultimate milk molar is never replaced in Mastodon or Elephas so far as observation has yet shown." He further remarks on ". . . the inconvenience of designating the molars in Mastodon and Elephas by successive numbers ranging from one to six or seven, which include both milk and true molars without distinction in the same numerical category . . .", and himself employs the terms "antepenultimate," "penultimate" and "last." He notes that ". . . this [terminology] is the more necessary as the theoretic first or preantepenultimate milk molar . . . [present in many other pachydermatous

[1] Falconer, 1868, Palæontological Memoirs, I, p. 89; II, p. 39, footnote; and 1846 (1847), 'Fauna Antiqua Sivalensis,' Pl. XIV, Fig. 4.

Fig. 2. (?) *Rhynchotherium* (*Dibelodon*) *edensis* Frick, referred left ramus containing dp_2 (broken), dp_3, dp_4, m_1 in germ, and tusk.

Outer view × 1/6. (2A) Inner view, greatly reduced scale, showing roots of teeth and tusk. (See Figs. 8 and 25.) Amer. Mus. 18216. Eden Pliocene, California.

Fig. 3. (?) *Rhynchotherium* (*Dibelodon*) *edensis* Frick, referred mandibular fragment with left dp_3, very slightly worn, and part of alveolus dp_2.

Outer view × 1/6. (See Fig. 9.) Amer. Mus. 18216. Eden Pliocene, California.

Figs. 4A–B. For comparison with (?) *R. edensis* Frick, inner views of anterior extremity of left ramus greatly reduced of:

(A) *Mastodon americanus*, Amer. Mus. 14345; and (B) "*R. shepardi* Leidy" Cope, 1893, Amer. Mus. 8532. Blanco, Texas specimen.

Fig. 5. *Trilophodon* (*Serridentinus*) *productus* Cope, dp_2, dp_3, and dp_4 in referred mandibular fragment of right side.

Inner view × 1/6. (See Fig. 10.) Amer. Mus. 21113. Santa Fé, New Mexico.

Fig. 6. *Trilophodon* (*Serridentinus*) *productus* Cope, left ramus of nearly complete referred mandible containing p_3, dp_4, p_4 unerupted, m_1, m_2 erupting, also tusks, and showing in dotted outline roots of teeth and tusks.

× 1/6. (See Figs. 11 and 24.) Amer. Mus. 21112. Santa Fé, New Mexico.

Fig. 7A. *Trilophodon* (*Serridentinus*) *productus* Cope, left ramus of complete mandible of neotype, containing m_2, m_3, and tusks, and showing in dotted outline roots of teeth and tusks, anterior root of m_2 being partly absorbed.

Outer view × 1/6. (See Figs. 12 and 23.) Amer. Mus. 21111. Santa Fé, New Mexico.

Fig. 7B. *Trilophodon* (*Serridentinus*) *pojoaquensis*, new species, referred, in heavy outline, left ramus of large mandible containing m_2, m_3, and portion of large tusk.

Outer view × 1/6. Amer. Mus. 21123. Santa Fé, New Mexico.

genera and constantly suppressed in the mastodons], is occasionally met with in the African elephant." He states as well that ". . . the whole evidence . . . is that, ordinarily, the premolars are entirely suppressed in *M. Ohioticus* (*americanus*), in both jaws [and that] there is nothing, therefore, in the mode of succession of the teeth in this species, to show where the deciduous series terminates and the true molars begin . . . In *Dinotherium* the two last premolars are developed, the two anterior being suppressed . . ." (I, p. 95).

Von Meyer in 1867 under *M. angustidens* figures a palate (Pl. III, Fig. 1) from Heggbach, showing three teeth, which he calls the first to second premolars and third milk molar [p^3, p^4 and m^1, and anterior to the first tooth a prominent double-rooted alveolus which he takes to represent the "first milk tooth" [dp^2]. He figures as well, from Messkirch, a "first milk tooth" (Figs. 14 and 15), and from Heggbach, a much larger "first premolar" which may represent the tooth corresponding to the lost antero-most tooth of the Heggbach maxillary specimen, and also figured from Serro de San Isidro a smaller tooth, of similar but simpler form to the Messkirch, as a "first lower back tooth" (Pl. V, Figs. 8–9) [the last probably represents p_3]. Von Meyer further depicts the considerable difference existing between the above premolars and those referred to *M. turicensis* as seen in his figures of the "first and second premolars" (p^3_3–p^4_4) from Elgg (Pl. II, Fig. 2; Pl. V, Figs. 1 and 2).

Cope (1877)[1] figures under *T. productus* "first to fourth molars," four teeth said in the text to have been associated in an immature mandible from Santa Fé and to represent the "first and second premolar," "third premolar of the milk series" and "first molar" [? p^3 (fragmental), p^4 (broken), m^1 (slightly worn) and m^2 (erupting)]; and states (1889) ". . . It is the only species in which three superior premolars have been demonstrated, other species having generally two . . ."

Lydekker (1880)[2] concludes that the mastodons may develop as many as nine molar teeth, three of the milk series, three replacement premolars, and three true molars (he considers the three milk and three true molars as forming the "horizontal series"); and notes that in all species the whole of the horizontal series is always developed, but that in the elephant premolars are only known to be developed in *E.* (*Archidiskodon*) *planifrons*, that in *M.* (*giganteus*) *americanus* and *M.* (*Pentalophodon*) *sivalensis* no premolars are developed, that in *M.* (*Trilophodon*)

[1] Cope, E. D., 1877, Ann. Rep., Chief of Engineers, Part 2, p. 309, Pl. LXXI, Figs. 1 and 2.
[2] Lydekker, R., 1880, Pal. Indica, (10) I, p. 198.

angustidens and *M.* (*Stegolophodon latidens* only the two last premolars are developed, and that ". . . there is good evidence that in one species of mastodon, at least, . . ." that (citing Cope's very doubtful interpretation of the maxilla of *M.* (*Serridentinus*) *productus*, Pl. LXXI, Figs. 1 and 2) three premolars are developed.

Leidy (1896) figures under *M. floridanus* (Pl. IV, Figs. 9–11) a maxillary specimen containing a "first premolar" and "third milk molar [p^3 and dp^4]," and in germ beneath the latter the "second premolar [p^4]" (Fig. 20), and m.[1] (The p^4 exhibits quite a different cusp arrangement from that of specimens from Simorre, New Mexico, and Texas.) Leidy further figures (Pl. IV, Figs. 8 and 1, 2, 6, and 7) a "first premolar [p^3]" (Fig. 20) of smaller size than the above, and two unassociated lower "first premolars" [p_3]. (The latter are suggestive of specimens from New Mexico and Texas.)

Andrews (1908)[1] figures under *Phiomia* (*Palæomastodon*) *wintoni*, an immature mandible showing a small anterior alveolus followed by two milk molars, and a first true molar, and beneath the milk molars the third and fourth premolars in germ. He remarks that "In the upper jaw, all the milk-molars are replaced by premolars, instead of only the posterior two, as in the mandible, and, so far, the upper dentition retains a more primitive character than the lower; . . . [that] in *Palæomastodon*, all the premolars and molars remain in use simultaneously . . . [that] the most significant character . . . seen in the light of the subsequent history of the dentition, is the sudden enlargement of $m\frac{2}{2}$ and $m\frac{3}{3}$ compared to $m\,\frac{1}{1}$; . . . [and that] in the next stage of which anything is known, . . . *Tetrabelodon angustidens* . . . there are three milk-molars in each jaw, all being replaced by premolars in the upper jaw, the posterior two only in the lower jaw . . ."

Schlesinger (1917) figures under *M. angustidens* a remarkably interesting maxillary fragment from Guntersdorf,[2] depicted as containing in the alveolar border the "first to third milk molars [dp^2–dp^3]" and "first molar teeth," and in germ inferior to the two anterior milk molars "premolars two and three [p^2–p^3]," and inferior to the last milk tooth, the empty socket of "premolar four." The specimen, as drawn and described, witnesses the occurrence, in this form at least, of a successor

[1] Andrews, 1908, Philos. Trans. R. Soc. of London (B) CXCVI, p. 400, Pl. XXXVII, Figs. 2 and 3.
[2] Schlesinger, 1917, Denkschriften K. K. Naturhist. Hofmuseums, I, Pl. II, Figs. 2–4, and Pl. III Fig. 1.

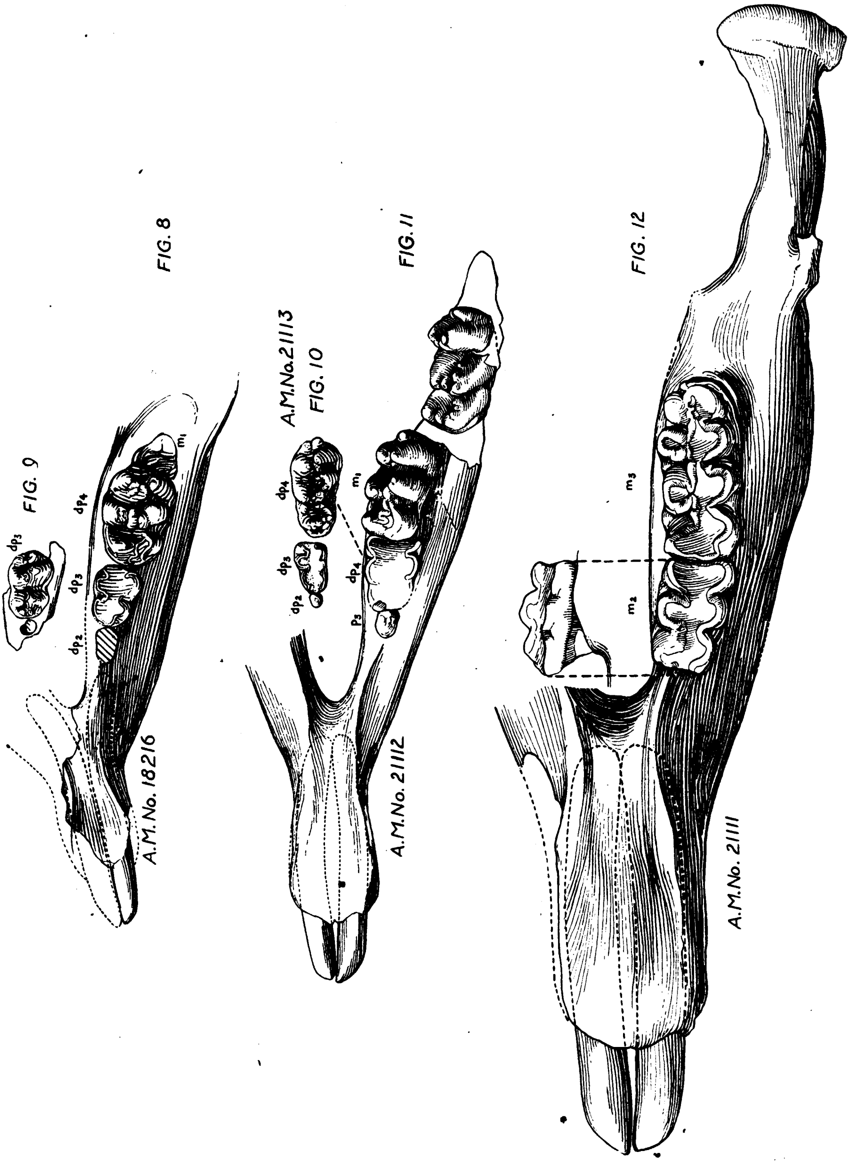


Fig. 8. (?) *Rhynchotherium* (*Dibelodon*) *edensis* Frick, left ramus of referred mandible (slightly reconstructed) containing dp_2 (broken), dp_3, dp_4, m_1 in germ, and tusk (root outline dotted).

Occlusal view × ⅙. (See Figs. 2 and 25.) Amer. Mus. 18216. Eden Pliocene, California.

Fig. 9. (?) *Rhynchotherium* (*Dibelodon*) *edensis* Frick, referred, left dp_3 (very slightly worn), and partial alveolus dp_2.

Occlusal view × ⅙. (See Figs. 3 and 9.) Amer. Mus. 18216A. Eden Pliocene, California.

Fig. 10. *Trilophodon* (*Serridentinus*) *productus* Cope, dp_2, dp_3 (worn), and dp_4 (erupting) in referred mandibular fragment of right side, reversed.

Occlusal view × ⅙. (See Fig. 5.) Amer. Mus. 21113. Santa Fé, New Mexico.

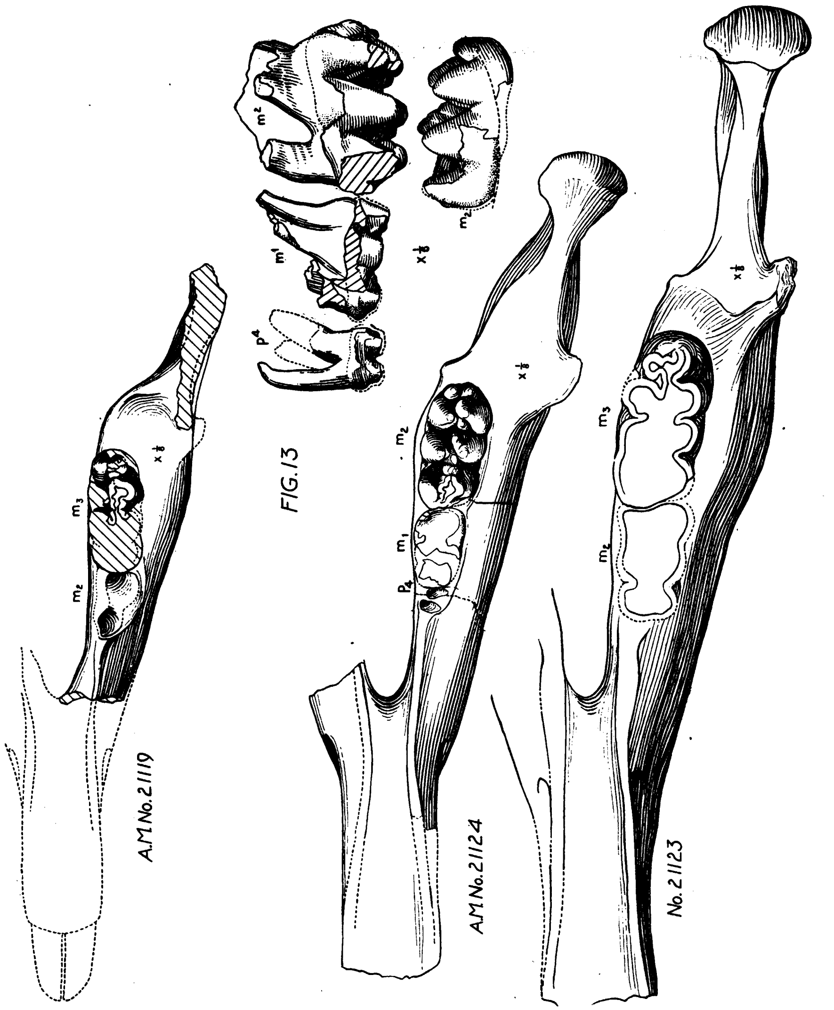


Fig. 11. *Trilophodon* (*Serridentinus*) *productus* Cope, left ramus and symphysis of nearly complete referred mandible showing p_3, dp_4, m_1, m_2 (erupting), and tusk (root outline dotted).

Occlusal view × 1/6. (See Figs. 6 and 24.) Amer. Mus. 21112. Santa Fé, New Mexico.

Fig. 12. *Trilophodon* (*Serridentinus*) *productus* Cope, neotype, left ramus of complete mandible containing m_2, m_3, and tusks (roots outline dotted).

Occlusal view × 1/6. (See Figs. 7A and 23.) Amer. Mus. 21111. Santa Fé, New Mexico.

Fig. 13. *Trilophodon* (*Serridentinus*) *productus* Cope, Amer. Mus. 21119; portion of referred left ramus with m_2 alveolus, and m_3 (broken).

Dotted portion hypothetical. Occlusal view × 1/8. (See m_3, Fig. 22D.) Santa Fé, Miocene, New Mexico.

Trilophodon (*Serridentinus*) *pojoaquensis*, new species, Amer. Mus. 21124; referred left ramus of nearly complete immature mandible showing root of p_4, m_1 (greatly worn), and m_2 (erupting).

Occlusal view × 1/8. P^4, m^1, m^2, right (reversed) of same individual. Inner view × 1/6. Santa Fé Miocene, New Mexico.

Trilophodon (*Serridentinus*) *pojoaquensis*, new species, Amer. Mus. 21123; left ramus of paratype containing m_2–m_3.

Occlusal view × 1/8. (See Figs. 1B and 7B.) Santa Fé Miocene, New Mexico.

to the antero-most milk tooth of the upper jaw.[1] The same author figures a maxillary specimen from Laaerberg (Pl. XII, Figs. 1–3), referred to *Tetralophodon longirostris* Kaup, which contains the three milk molars [dp^2–dp^4], and p^3 in germ. The drawing indicates the next to the last milk tooth (at least) to have a vertical successor as in *T. angustidens* but the two last milk teeth of this form to be three- and four-crested respectively versus two-and-one-half- and three-crested, and the dp^2 to be proportionately small relative to dp^3 as compared to *T. angustidens.* He further figures under the same species from the Laaerberg locality (*loc. cit.*, footnote) a larger (Pl. XI, Fig. 3 and Pl. XIII, Fig. 1) "p_3" [p_4], unworn, and a smaller (Pl. XII, Fig. 5) "p_3" [p_4], unworn, and from Meidling a remarkably large and much worn "p_4" whose anteroposterior diameter is over 40 per cent greater than that of the smaller Laaerberg tooth.

Boule and Thevenin (1920),[2] in their admirable chapter on the mastodons of Tarija, follow Pavlow and those other writers who continue to designate the proboscidean sequence as consisting of $m^{1}_{1}-^{6}_{6}$. For while these authors state that in (certain of) the mastodons as in the elephants there are no true premolars, the series consisting of three milk molars and three molars, they contend that it is possible that in the Tarija species, on account of the length of the roots and the similarity of the third of the anterior three teeth and the first true molar, that the three anterior teeth may really represent the true premolars, the milk molars being perhaps lost very early or reabsorbed before birth.

In regard to the tusks, Corse (1799) states that the deciduous tusks in the upper jaw of the Asiatic elephant are shed between the first and second years and six months or more after the eruption of the permanent pair.[3] Lydekker (*loc. cit.*) notes that the permanent tusks of the upper

[1] The unusual size of the premolar figured by Dr. Schlesinger in germ beneath dp^3 (the former nearly equaling the latter in anteroposterior diameter), the vacant socket below dp^4, the great size of the figured m^1 as compared to dp^4, and the reported somewhat fragmentary condition of the jaw itself, suggest the possibility of an error having occurred in the reconstruction and therefore interpretation of this specimen. Premolars are known to be normally small relative to the respective milk molars, as observed in such American specimens as Leidy's Florida maxilla (Nat. Mus. 3064) and the Santa Fé mandible (Amer. Mus. 21112, Fig. 6); and in such a European specimen as Lartet's Simorre mandible (Pl. IV). In the Heggbach maxilla (figured by von Meyer), the m^1 corresponds in size to "m^1" of the Guntersdorf maxilla, a large double-rooted alveolus appears anterior to p^3, which is small relative to p^4. An interpretation that would better accord with our understanding of the normal would therefore suggest: first, that the posterior premolar germ is misplaced and actually represents p^4, belonging in the empty socket below dp^4 and not below dp^3; and, second, that the relatively large "first molar" tooth represents a second and larger individual. The premolars from Laaerberg figured as "p_3" resemble very closely the detached p_4 germ from Santa Fé (Fig. 15C), and a similar but larger tooth figured from Meidling (anteroposterior diameter 54.5 mm.) equals in size the largest specimens from Nebraska and Texas.

[2] Boule and Thevenin, 1920, Mammifères fossiles de Tarija, p. 40.

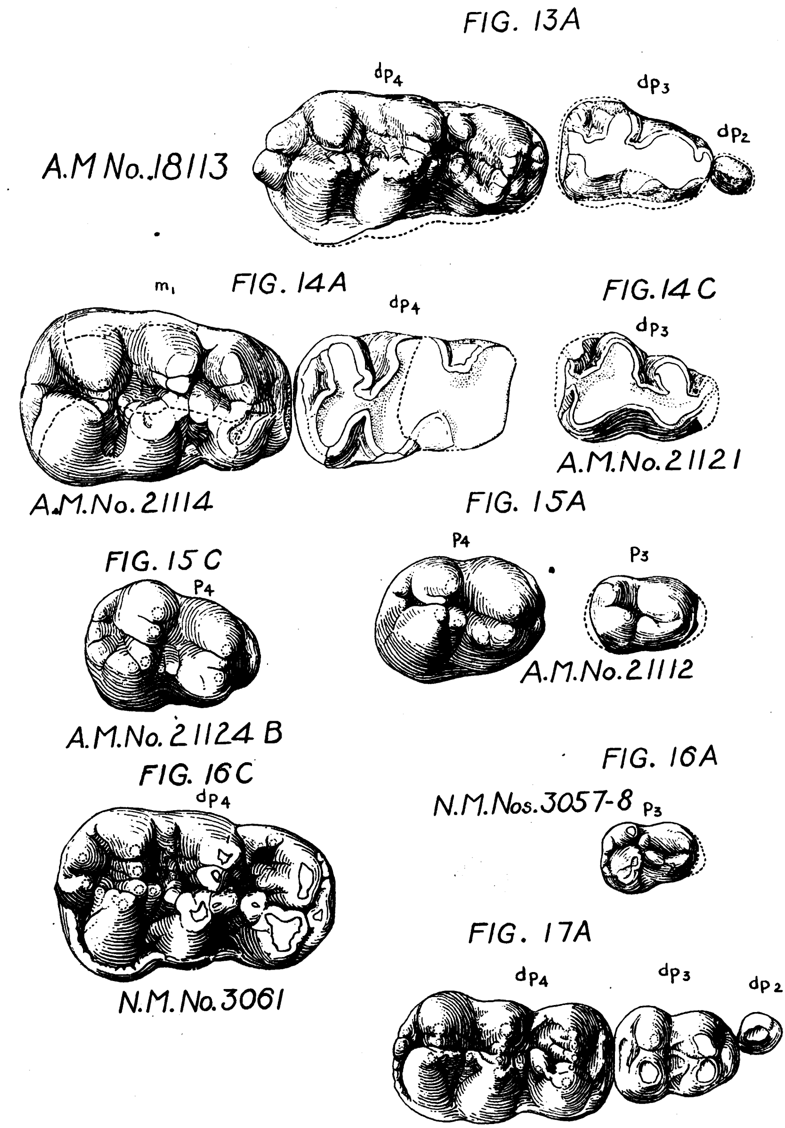
[3] Corse, 1799 [1809] Philos. Trans. R. Soc. London, XVIII, p. 512. The symphysis of an immature mastodon mandible in the collection of the Carnegie Museum (A. O. Peterson, 1925, Bull. Carnegie Mus., 'Pleistocene Fauna of Frankfort Cave, Pennsylvania') is remarkable in containing two pairs of small tusks, one pair lying above and slightly inward of the other, the specimen recalling Corse's description of the deciduous and permanent tusks of the Asiatic elephant, and the alveoli noted by Barbour as present above the tusks of a Nebraska Pliocene mandible.

jaw are preceded by deciduous tusks in at least some fossil species as in the living elephants, but both he and Lartet remark that it is not known whether the tusks that sometimes occur in the lower jaw were ever preceded by a deciduous pair, and Andrews (*loc. cit.*) concludes that it is most probable that in *Phiomia* they could ever have been replaced. It may be noted that the dentition of the mammalian lower jaw is apt to be more precocious than that of the upper jaw. In *Phiomia*, as observed by Andrews, the upper dentition retains a more primitive character than the lower, all three of the milk molars being replaced by premolars instead of only the posterior two.

SUMMARY

It seems advisable at this point to summarize from the detailed discussion of evidence and of hypotheses set forth in the latter sections of the paper and to state the known facts and tentative conclusions concerning, first, the general problem of tooth sequence in the Proboscidea, and, second, the characters of the mastodon species of Santa Fé, New Mexico. In regard to the former it is observed that in long-symphysised Miocene trilophodonts, such as those of New Mexico, of Texas, and of Nebraska, as in the case of *Trilophodon angustidens* of Europe, three milk molars are present in both jaws; that the two posterior of these are followed by well-developed premolars, the antero-most milk molar being without a vertical successor in the lower jaw at least,[1] and in the upper jaw being relatively large and more persistent than that of the lower; that dp^3_3 and dp^4_4 have relatively small and simplified vertical successors which erupt locked between the roots of their respective deciduous predecessors, p^3–p^4 being oviform to quadrate and p_3–p_4 being more elongate with tendency to ridges and trefoils variably developed; and that the replacement premolars are crowded forward and shed during the eruption of the molars, so that the full tooth-series of the adult consists alone of the variably elongated m^2_2 and m^3_3. It is noteworthy that each of the milk teeth is prognostic to a certain degree of the permanent tooth of the next posterior position. While the tooth sequence in such long-symphysised Miocene species is of this one general type, certain of their premolars, and those of other species of a similar stage of tooth replacement, may differ markedly from one another as prominently exampled in specimens of the p^4.

[1] See discussion under "Tooth Sequence" and footnote regarding Guntersdorf maxillary specimens, pp. 150, 153.



Figs 13A–17A. Crown views of mandibular teeth of trilophodont mastodon species $\times \frac{1}{2}$. (See p. 137.)

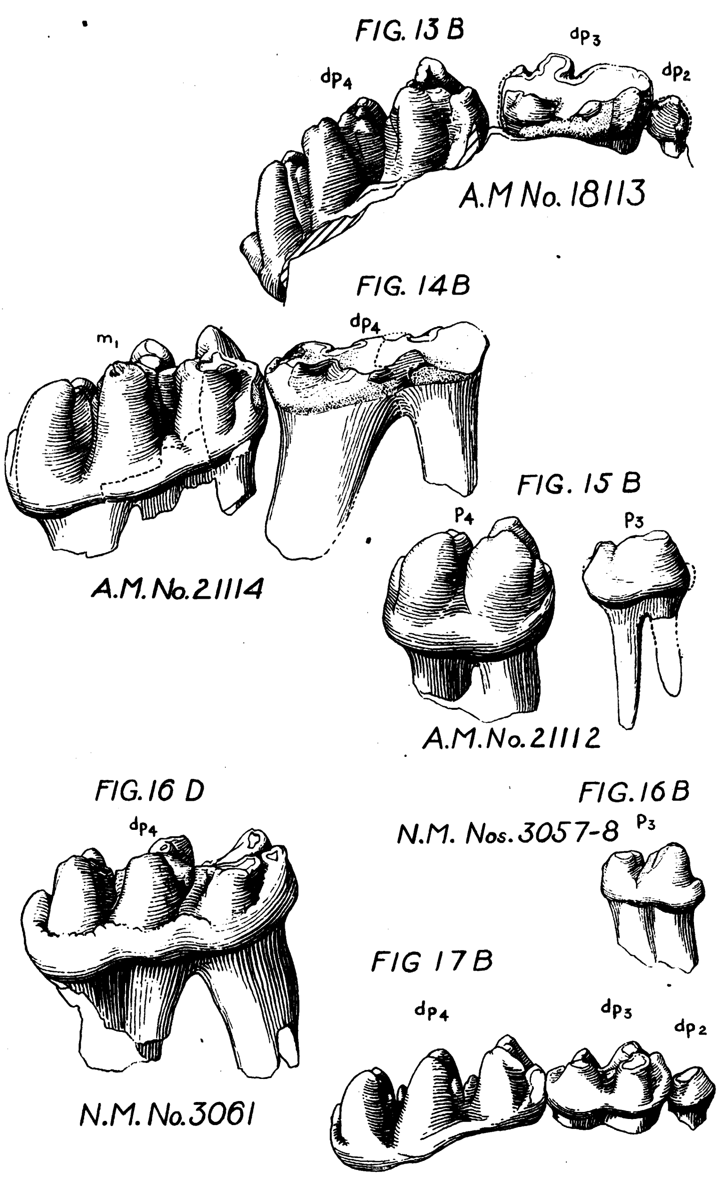
Figs. 13A–B. *Trilophodon* (*Serridentinus*) *productus* Cope, referred specimen, dp_2, dp_3 (greatly worn), dp_4 (erupting) from fragment of the right ramus of a small individual.

(A) Occlusal and (B) outer views $\times \frac{1}{2}$. (See Figs. 5 and 10.) Amer. Mus. 18113. Santa Fé, New Mexico.

Trilophodon (*Serridentinus*) *productus* Cope (14A and B).

Figs. 14A–C. *Trilophodon* (*Serridentinus*) *productus* Cope, referred specimens: (14A and B) dp_4 (greatly worn) and m_1 of right side found *in situ*. Smaller individual than Amer. Mus. 18213.

(A) Occlusal and (B) outer views $\times \frac{1}{2}$. Amer. Mus. 21114. (C) Dp , left (reversed) $\times \frac{1}{2}$. Amer Mus. 21121. Santa Fé, New Mexico.



Figs. 13B–17B. Outer views of mandibular teeth of trilophodont mastodon species × ½. (See p. 136.)

Figs. 15A–C. *Trilophodon* (*Serridentinus*) *productus* Cope: (15A and B) p_3, and p_4 (germ, reversed) of referred immature mandible.

(A) Occlusal and (B) outer views × ½. (See Figs. 6 and 11.) Amer. Mus. 21112. (15C) Referred p_4 left (reversed). Amer. Mus. 21124B. Santa Fé, New Mexico.

Figs. 16A–D. (?) *Trilophodon* (*Serridentinus*) *leidii*, new species: (16A and B) referred p_3 right, partially reconstructed from two teeth of a small individual.

(A) Occlusal and (B) outer views × ½. (Figured by Leidy, 1896, Pl. IV, Figs. 1 and 6.) Nat. Mus. 3057 and 3058. (16C and D) dp_4, reversed. (C) Occlusal and (D) outer views × ½. (Figured by Leidy, 1896, Pl. III, Fig. 2.) Nat. Mus. 3061. Florida Miocene.

Figs. 17A–B. *Trilophodon angustidens* Cuvier, referred right dp_2–dp_4.

(A) Occlusal and (B) outer views (reversed) × ½. After Amer. Mus. Warren Coll. cast. Sansan Miocene.

The dental stage represented by the Oligocene genus, *Phiomia*, of Andrews[1] on the whole, while very suggestive of, markedly differs from the Trilophodon stage. (The elongation of the symphysis, as noted below, lies midway between the extremes of the *Trilophodon* group.) Thus, the replacement premolars of *Phiomea* are well developed and noticeably large as compared with dp_3 and dp_4, the p_3 being actually longer than dp_3; and the $m\frac{1}{1}$–$m\frac{2}{2}$ and particularly $m\frac{3}{3}$ are of relatively small or normal mammalian proportions, with the result that extreme forward progression of the posterior teeth is absent, and the alveolar borders of the adult are able to accommodate at one time $p\frac{3}{3}$–$m\frac{3}{3}$. The illustrations of various authors indicate that the replacement of the teeth in tetralophodont forms, such as the long-symphysised *Tetralophodon longirostris* (and perhaps the shorter-jawed stegomastodons (*Anancus arvernensis*) as well), were of generally similar type to the *Trilophodon*, the antero-most milk molars being apparently smaller relative to the premolars, and $dp\frac{4}{4}$ and $m\frac{1}{1}$, the one always prophetic[2] of the other, being four-crested.

As contrasted with the peculiar but vastly more typical mammalian tooth sequence of the above-described genera, the depressed-beaked (?) *R.* (*D.*) *edensis* (as presumably *R. shepardi* Cope of the Blanco), and such short-jawed mastodon forms as *M. andium* and *M. americanus*, apparently never develop vertical successors to the three milk molars ($dp\frac{2}{2}$–$dp\frac{4}{4}$ present in all forms), the replacement of the teeth taking place alone from back to front and thus being entirely horizontal. That these Plio-Pleistocene forms, however, which have no true premolars, were represented in earlier times by forms that had premolar teeth, is indicated by the figures of von Meyer of the somewhat *M. americanus*-like-toothed *M. turicensis* from the Mid-Miocene of Elgg, which display p^3 and p^4 present, but manifestly functionless, being unworn and crowded forward out of position over the tusk roots. Similarly, the premolarless elephantoid species were evidently once represented by more normally toothed ancestors, as is witnessed by the rudimentary germs present in the Siwalik specimens referred to *E.* (*A.*) *planifrons*.

The Santa Fé mastodons and the Siwalik elephant may thus together broadly be considered to typify a stage in the odontogeny of the Proboscidea intermediate to the comparatively primitive dental state represented by Oligocene *Phiomia*, and to the extremely reduced state oc-

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[1] Andrews, 1903, Philos. Trans. R. Soc. of London (B), CXCVI, p. 110, Figs. 10–13; 1908, *idem*, CXCIX, p. 400, Pls. XXXI and XXXII.

[2] Similarly in *Dinotherium* the three-crested $dp\frac{4}{4}$ is prophetic of the three-crested $m\frac{1}{1}$; $m\frac{2}{2}$, $m\frac{3}{3}$ remaining two-crested and more (?) primitive.

curring in those Plio-Pleistocene forms in which the alveolar border and symphysis have shortened, the m^3_3 have further increased in length as compared with the m^2_2, and the replacement premolars have entirely disappeared. In the following key and adjoining diagram (Fig. 1C,)[1] an attempt is made to throw into relief the characters of the immature and mature jaws of the two extreme dental types and those of the intermediate stage, illustrated in the milk and replacement dentitions of: 1, *Phiomia wintoni;* 2, *Trilophodon* [*T.* (*S.*) *productus* and allied species]; 3, *Elephas* (*Archædistodon*) *planifrons;* 4, (?) *Rhynchotherium* (*Dibelodon*) *edensis* and *R. shephardi;* 5, *Mastodon americanus;* and 6, *Loxodon africanus.*

KEY

M^2_2 M^3_3 not greatly enlarged

I. APPROXIMATELY NORMAL MAMMALIAN TOOTH SEQUENCE.—

1. *Phiomia* (*Palæomastodon*) *wintoni* Andrews (see Andrews, 1908, associated mature jaws, Pl. XXXI, p. 396, and immature mandible, Pl. XXXII, Figs. 2–4), in which dp_3 and dp_4 have large vertical successors, the molars are not enlarged, the horizontal replacement of the teeth is at a minimum, the whole of the permanent series (p^3_3–m^3_3) being in place at one time; the anteroposterior diameter of m^3 exceeds that of m^2 by some 16 per cent of the latter; m^3 and m_3 are of about the same length, relatively unelongate, and equal approximately 25 per cent of the symphyseal length[2] (this may be equivalent to 1.19 per cent of the alveolar-distance, see below).

M^2_2 M^3_3 greatly enlarged

II. LAST TWO MILK MOLARS ALONE (IN LOWER JAW AT LEAST) SUCCEEDED, OR TENDING TO BE SUCCEEDED, BY TRUE PREMOLARS.—

A. JAWS LONG.—

2. *Trilophodon* (*Serridentinus*), in which the premolars are much smaller than the milk molars; the last two molars are so much enlarged that in the aged adult the m^2_2–m^3_3 completely occupy the alveolar border to the exclusion of all the anterior teeth; the anteroposterior diameter of m^3 variably exceeds that of m^2, that of m_3 that of m^3 (by 10 to 15 per cent), and the relative elongation of m_3 may both exceed or be exceeded by that of the symphysis, which may be of either moderate or tremen-

[1] In the figures the greatest distance (xy) occupied at one time by members of the cheek-tooth series is brought to unity, the two illustrations under each species being drawn to the same scale, and the mandibles aligned so far as possible on the posterior border of the symphyses (p. s.).

[2] A variation (individual or specific) exists in the relative position of the posterior border of the symphysis (p. s.) in *Phiomia, i. e.,* in our figure "p. s." =position in specimen figured by Andrews; "Z" = approximate position in Amer. Mus. specimen No. 13476; "Z′" = approximate position in *P. osborni* Matsumoto, Amer. Mus. 13468, though the extreme posterior position in the latter may be due to injury and thus be abnormal.

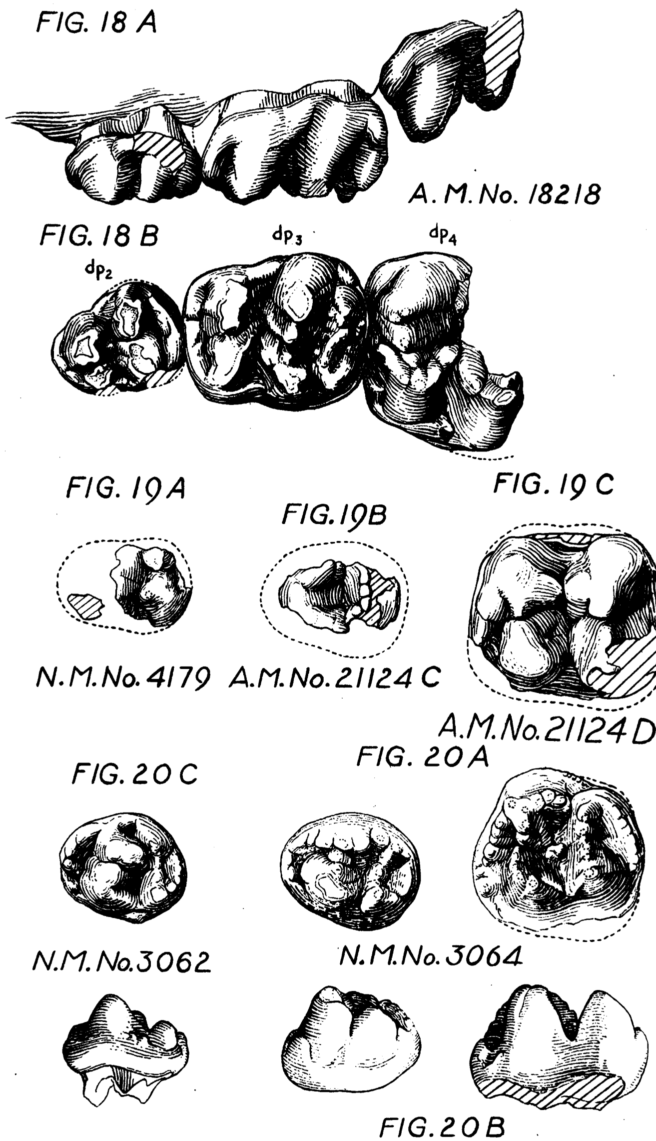

Fig. 18. (?) *Rhynchotherium* (*Dibelodon*) *edensis* Frick, dp^2, dp^3, and dp^4 fragment (erupting) of referred left maxillary specimen.

Outer and occlusal views × ½. Amer. Mus. 18218. Eden Pliocene, California.

Fig. 19A. *Trilophodon* (*Serridentinus*) *productus* Cope, fragmental (?) p^3 right, of Cope's referred maxillary specimen. Dotted outline supplied after von Meyer (1828, Pl. III, Figs. 8, 9, and 10).

Occlusal view × ½. (Figured by Cope, 1874, Pl. LXXI, Figs. 1 and 2.) Nat. Mus. 4179. Santa Fé, New Mexico.

Figs. 19B–C. *Trilophodon* (*Serridentinus*) *pojoaquensis*, new species, referred. (B) Fragmental (?) p^3 right.

Dotted outline after Florida p^3 (Fig. 20). × ½. Amer. Mus. 21124C. (C) P^4 right. × ½. Amer. Mus. 21124D. Santa Fé, New Mexico.

Figs. 20A–C. (?) *Trilophodon* (*Serridentinus*) *leidii*, new species: (A and B) p^3 and p^4 germ, right, of type specimen.

Occlusal and outer views × ½. (Figured by Leidy, 1896, Pl. IV, Figs. 9, 10, 11.) Nat. Mus. 3064. (C) Referred smaller p^3 left (reversed). Occlusal and outer views × ½. (Leidy, Pl. IV, Fig. 8.) Nat. Mus. 3062. Florida Miocene.

dous length. The genus might well stand subdivision,[1] as at present constituted including a number of highly specialized, but perhaps in a large measure contemporaneous, forms. The more typical species considered below visibly fall into three subgroups distinguished by a progressive decrease in the elongation of their respective symphyses as observed in respect to the alveolar-distance (this alluding, in contradistinction to alveolar-length, to the distance between the protuberance at the mid-inner corner of the alveolar pouch and the posterior border of the symphysis).

SYMPHYSEAL-LENGTH EXCEEDING ALVEOLAR-DISTANCE.—*T. angustidens* (Tournan and Sansan specimens)[2] and in *T. giganteus* Osborn, in which the anteroposterior diameter of m^3 greatly exceeds that of m^2 (40+ per cent), and the elongate m_3 represents but a relatively small proportion (25 to 30 per cent) of the great symphyseal-length (as also apparently in *T. lulli* Barbour).

SYMPHYSEAL-LENGTH BUT SLIGHTLY EXCEEDING ALVEOLAR-DISTANCE.—*T.* (*S.*) *pojoaquensis* Santa Fé type and referred specimens, *T.* (*S.*) *abeli* and *T.* (*S.*) *osborni*, in the first of which at least the m^3 is also much enlarged relative to m^2 (40 per cent), and in all of which the m_3 is evidently equivalent to a greater per cent (35 to 40 per cent) of the somewhat shorter-proportioned symphysis.

SYMPHYSEAL-LENGTH CONSIDERABLY LESS THAN ALVEOLAR-DISTANCE.—*T.* (*S.*) *cimarronsis*, *T.* (*S.*) *serridens* (Clarendon skulls and jaws), *T.* (*S.*) *productus* (type and neotypic mandible), and *T.* (*S.*) *willistoni*, in which the anteroposterior diameter of m^3 relatively only slightly exceeds that of m^2 (17 to 20 per cent), and the m_3 is equivalent to some 50 per cent of the moderate symphyseal-length (versus 25 per cent in *Phiomia* where symphyseal-length may nearly equal (1.19 per cent) the alveolar-distance).

B. JAWS SHORT.—

3. *Elephas* (*Archidiskodon*) *planifrons* Falconer and Cautley (hypothetical, after Fauna Antiqua Sivalensis, Pl. XII, Figs. 8, 9, 10, and 11; Pl. X, Fig. 10), in which a greatly reduced p_3 and p_4 are present in germ in the shortened jaw, although it is doubtful whether these were ever functional.

III. TRUE PREMOLARS NEVER DEVELOPED.—

4. (?) *Rhynchotherium* (*Dibelodon*) *edensis* Frick (see text figures), and *Rhynchotherium shepardi* Leidy, Cope, from Texas (see Cope specimen, Amer. Mus. 8532), in which the symphysis is relatively short and depressed and the last molars much enlarged.

5. *Mastodon americanus* Cuvier (see Warren figures and Amer. Mus. casts) and *M. Dibelodon*) *andium* Cuvier (see Boule figures), in which the beak is short relative to the anteroposterior diameter of m^3_3, which in the former tend to exceed m^2_2 by as much as 50 per cent.[3]

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[1] (?) *T.* (*S.*) *turicensis*, in which the premolars are relatively large but doubtfully functional, represents a stage between the Trilophodon and that represented by *E.* (*A.*) *planifrons*. (?) *T.* (*S.*) *leidii*, new species, in which the premolar status sonr ewhat parallels that in *Trilophodon*, represents a stage slightly in advance of the *Trilophodon*. *Tetralophodon longirostris* typifies a stage ostensibly equivalent to the *Trilophodon* among the tetralophodons.

[2] Measurements kindly supplied by Dr. W. D. Matthew from manuscript notes on Paris specimens.

[3] In the skull of the Warren Mastodon there is a difference of as much as 6 per cent between the anteroposterior diameter of homologous molars of the right and left series, the m^3's are slightly longer than the m_3's, and m^2 some 47 per cent longer than m^3. In the Shawangunk skull, m^3 is of the same general length as m_3, and is approximately 50 per cent longer than m.[2]

6. *Loxodon africanus* Blumenbach (*Loxodonta africana*) (see Amer. Mus. Specimens), in which the beak is also infinitesimal, and as in *E.* (*A.*) *planifrons* the posterior molars, through the addition and multiplication of ridges, are progressively greatly elongated (the teeth in the figures are provisionally interpreted as representing (?) dp_2–dp_4, and m_2–m_3).

To return to the discussion of the remains from New Mexico, among these, as previously remarked, as among those of similar forms from other localities, are specimens that vary greatly in size. This variation, which between two Santa Fé specimens amounts to as much as 60 per cent of the size of the smaller, is accompanied by very apparent diversity of development of the symphysis. Such differences clearly represent more than individual variation, and must be taken as indicative of specific if not of subgeneric character. It is recalled that Cope recognizes the presence of a large and small species, *T.* (*S.*) *serridens* and *T.* (*S.*) *cimarronis*, in his material from Texas. (To his species are here tentatively referred as paratypes two fine skulls and jaws from the Clarendon.) The one named New Mexican species, *T.* (*S.*) *productus*, is based on a moderate-sized mandible with a symphysis of moderate length. I take that specimen, representing the extreme upper limit in size, as the type of a new species, *T.* (*S.*) *pojoaquensis*, and refer to the same as paratypes two mandibles with notably longer symphysis and a splendidly preserved skull. This specimen exhibits an extreme elongation of the anterior maxillary-premaxillary area, and a quite unusual height and anteroposterior shortness of the cranium proper, the latter proportions being more like recent *Elephas* than American Pleistocene (*M. americanus*) or previously known Miocene mastodons (*T.* (*S.*) *serridens*, *T.* (*S.*) *willistoni*, etc.). It is interesting to remark a somewhat commensurate range of size to that observed amongst the last molars of these Miocene mastodons and noted also amongst premolars from the Snake Creek Pliocene, occurring in the last molar teeth of North American mammoths of the genus *Elephas*.

THE LONG-SYMPHYSISED MASTODONS OF THE SANTA FÉ MIOCENE, NEW MEXICO

Trilophodon (Serridentinus) productus Cope, and **T. (S.) pojoaquensis,** new species

Leidy, in 1873, described under *Mastodon obscurus* and *M. shepardi* some mastodon remains collected from the vicinity of Santa Fé by Governor Arny of New Mexico, stating, ". . . I think it probable, without being positive in the matter, that the mastodon remains above described [that is, these New Mexican specimens and others from Maryland and California] which have been referred to species under the names of *Mastodon obscurus* and *M. shepardi*, including those from New Mexico, belong to one and the same species . . . a near relation of the *Mastodon augustidens* of Europe." Cope, in 1874, noted that mastodon remains from Santa Fé represented a new species for which he proposed the name *Mastodon productus*, and took for the type a mandibular specimen which he had but recently found.

Our work in the Santa Fé region (as remarked above) has resulted in the obtaining of a considerable collection of mastodon material. Among this are immature specimens illustrative of various stages of the milk and replacement dentition, and a fine series of mature specimens that differ widely in size and in the degree of prolongation of the symphysis, and moderately in the tubercular arrangement of the teeth. Broadly considered, the variation in the remains parallels that observed in such other .long-symphysised trilophodont tetralophodonts as those of the Miocene of Texas and Nebraska, of the Miocene of Europe, and of the Lower Pliocene of Nebraska and of California. All are furnished with somewhat similar dorsoventrally compressed inferior tusks, slightly divergent and downwardly directed enamel-banded upper tusks, considerably produced mandibular symphysis, three-crested intermediate and four-crested last molars that developed single trefoils, and deciduous premolars with somewhat reduced vertical successors.

The skull characters of the various remains referred to these species, with the notable exception of the recent acquisition from New Mexico, two somewhat crushed skulls from Texas, and certain unavailable Nebraskan and European material, are as yet unknown, as are largely those of the skeleton. At the moment, no general comparison of the proportions and characters of these areas in the different species is,

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Figs. 21A–22D. Last molar teeth. (21A–C) (?) *Rhynchotherium* (*Dibelodon*). Eden, California, species; and (22A–D) *Trilophodon* (*Serridentinus*) Santa Fé, New Mexico, species. ×½.

Figs. 21A–C. (?) *R.* (*D.*) *edensis* Frick, referred specimens.

(A and C) M^3 unworn, of left side. Amer. Mus. 18219D. (B) M_3, worn, of left side. Amer. Mus. 18219. Eden Pliocene, California.

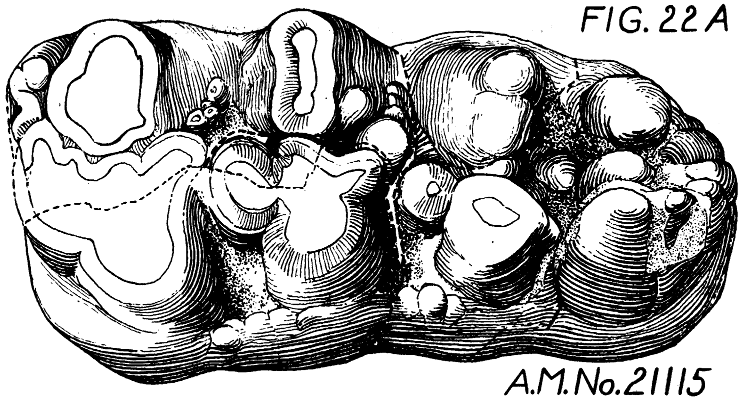
Figs. 22A–B. *T.* (*S.*) *pojoaquensis*, new species. Illustrating variation between: (A) M^3 left (broken) of type specimen (see Fig. 26).

Amer. Mus. 21115; and (B) M^3 right, unworn, of palatal specimen containing m^2–m^3 of both sides. Amer. Mus. 21118.

Figs. 22C–D. *T.* (*S.*) *productus* Cope. Illustrating difference in size between two tentatively referred specimens:

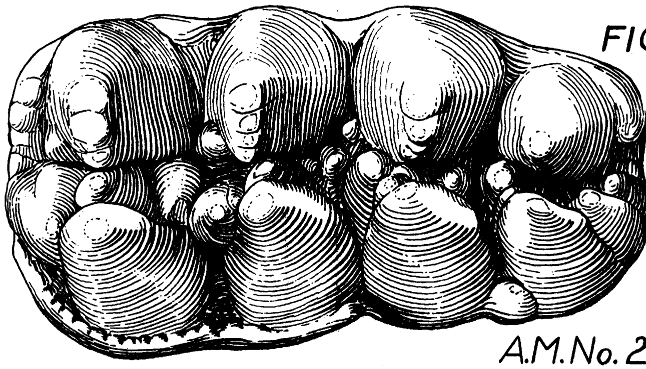
(C) M^3 right, moderately worn. Amer. Mus. 21116 (reversed); and (D) M_3 right, of small mandibular specimen. (See Fig. 13, in part.) Amer. Mus. 21119.

FIG. 22 A



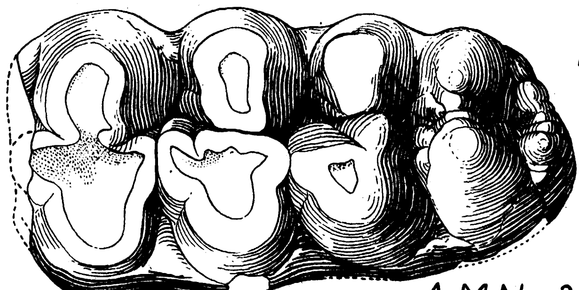
A.M. No. 21115

FIG. 22 B



A.M. No. 21118

FIG. 22 C



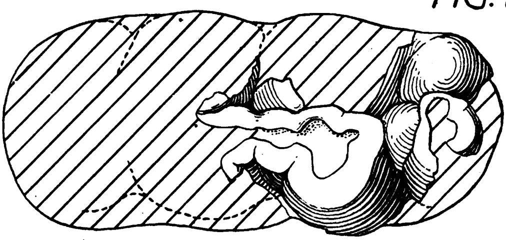
A.M. No. 21116

FIG. 21 C

D

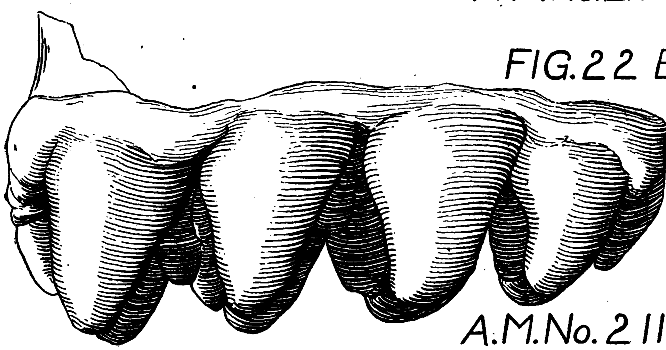
A.M. No. 18219

FIG. 22 D



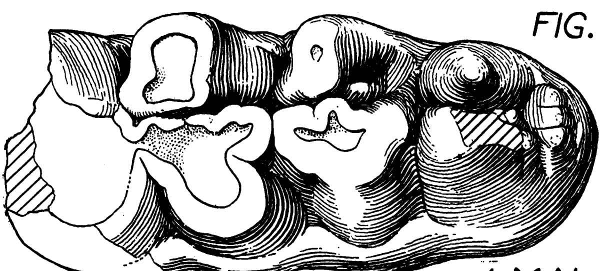
A.M.No.21119

FIG. 22 B



A.M.No. 21118

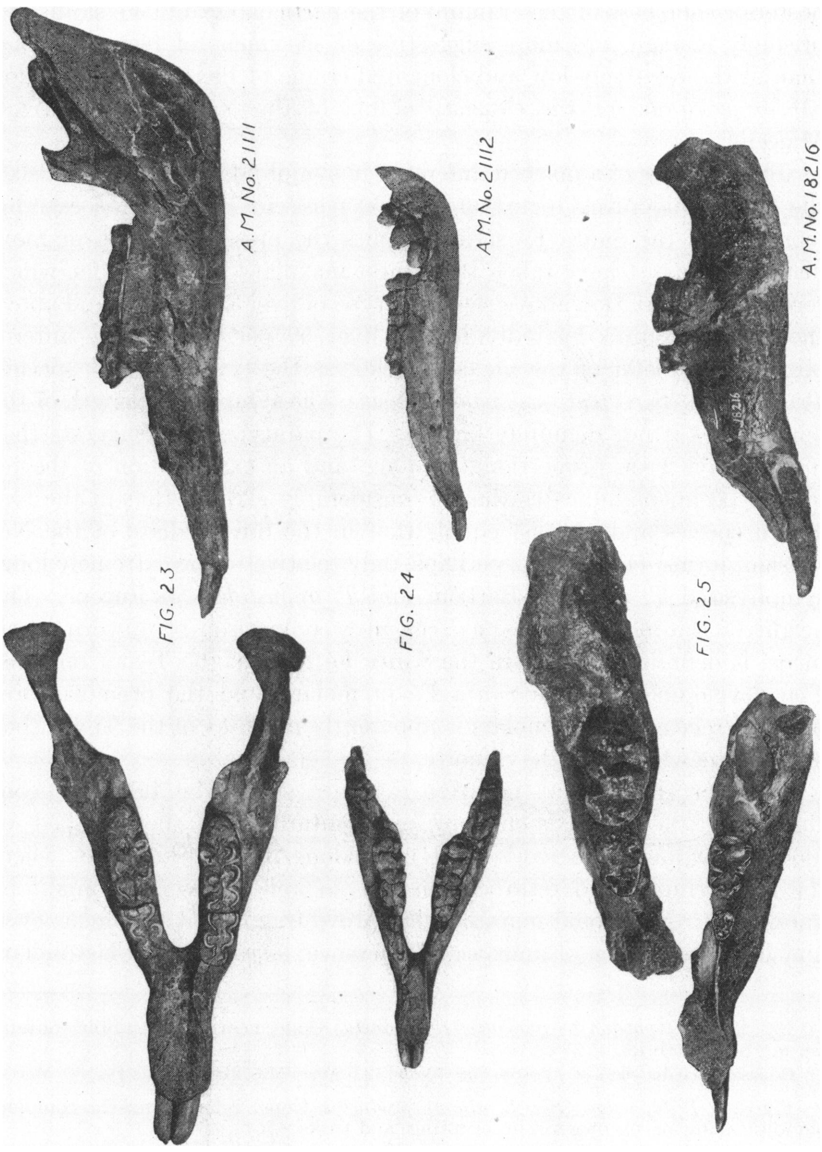
FIG. 21 B



A.M.No. 18219

FIG. 21 A

D
A.M.No. 18219


A.M. No. 21111
FIG. 23
A.M. No. 21112
FIG. 24
A.M. No. 18216
FIG. 25

therefore, possible. It is sufficient to remark that the height and antero-posterior shortness of the cranium of the particular Santa Fé skull, surprisingly enough, are more suggestive of specimens of recent *Elephas* than of the relatively low and elongated crania of Pleistocene mastodon (*M. americanus*) or the elongate crania of the Nebraska and Texas Miocene.

The presence of a marked difference in symphyseal length and in size, the latter amounting to upwards of 60 per cent between the extreme members of the Santa Fé series, implies the presence of two or more distinct forms. I have taken the largest maxillary specimen, one which represents a variation above the Cope type of over 35 per cent and above the smallest Santa Fé individual of over 50 per cent of the antero-posterior diameter of the m_3 (see table), as the type of a new species, *Trilophodon* (*Serridentinus*) *pojoaquensis*. The symphyseal length of the new species is not definitely known. The paratype skull suggests that it may have been proportionately long, and an examination of the referred specimens indicates that it considerably exceeds that in the two Texan species and at least equals that in the intermediate of the Nebraskan forms, being short, perhaps, only relative to the extremely long-symphysised *T.* (*S.*) *lulli* Barbour and *T. angustidens* of Europe. The height of the molar crowns, as seen in a comparison of unworn specimens, is definitely greater in the Santa Fé than in the Texan remains. The development of the Santa Fé premolars, and the premolar proportions relative to the molars is apparently much as in the Texan, but differs somewhat from the Simorre.

Whether the present negative evidence should be taken as conclusive of the non-existence of representatives of short-beaked or moderately long-deflected-beaked mastodons in the Santa Fé, where the long-symphysised tetrabelodons are so well represented, might be questioned. Additional material may prove fragmental specimens even now in the collection of unexpected reference; as the unworn last molars

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Fig. 23. *Trilophodon* (*Serridentinus*) *productus* Cope, neotypic mandible containing m_2, m_3 and tusks.

Occlusal and outer views $\times \frac{1}{12}$. (See Figs. 7A and 12.) Amer. Mus. 21111. Santa Fé, New Mexico.

Fig. 24. *Trilophodon* (*Serridentinus*) *productus* Cope, referred nearly complete mandible showing p_3, dp_4, m_1, m_2 erupting, and tusks. $\times \frac{1}{12}$.

(See Figs. 6 and 11.) Amer. Mus. 21112. Santa Fé, New Mexico.

Fig. 25. (?) *Rhynchotherium* (*Dibelodon*) *edensis* Frick, referred, mandible portions containing dp_2 (broken), dp_3, dp_4, m_1 in germ, and tusk of left side, and dp_3 and dp_4 of right side.

Occlusal and outer views $\times$ 1/6. (See Figs. 2 and 8.) Amer. Mus. 18216. Eden Pliocene, California.

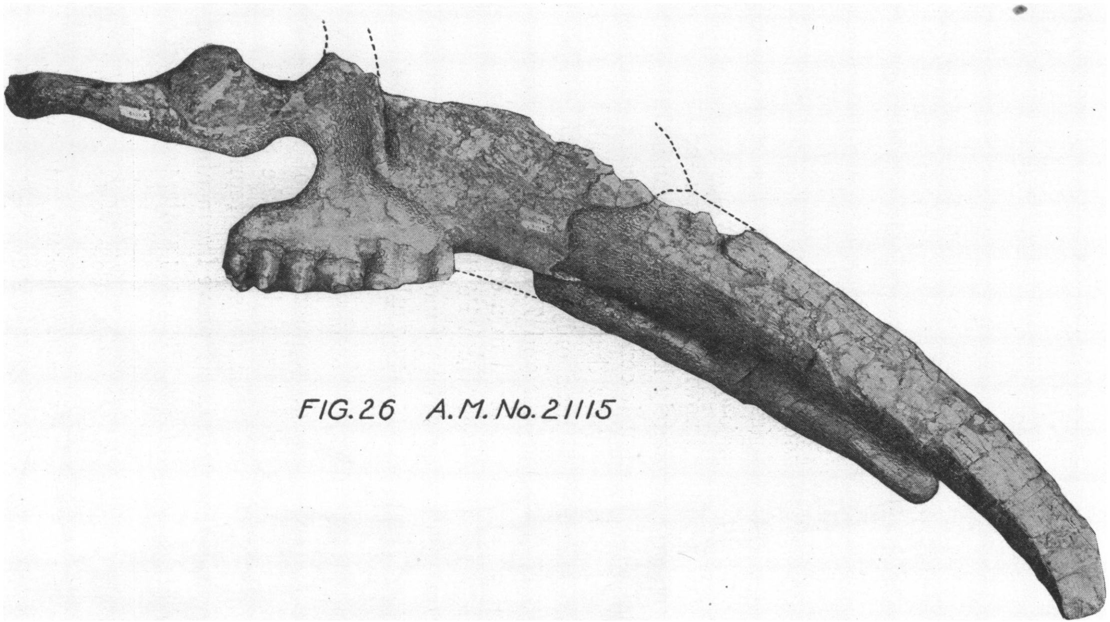

Fig. 26. *Trilophodon* (*Serridentinus*) *pojoaquensis*, new species, type specimen, skull fragment containing m^2–m^3 and tusks.

Outer view, teeth $\times \frac{1}{10}$ (tusks somewhat distorted). Amer. Mus. 21115. (See m^3, Fig. 22A.) Santa Fé Miocene, New Mexico.

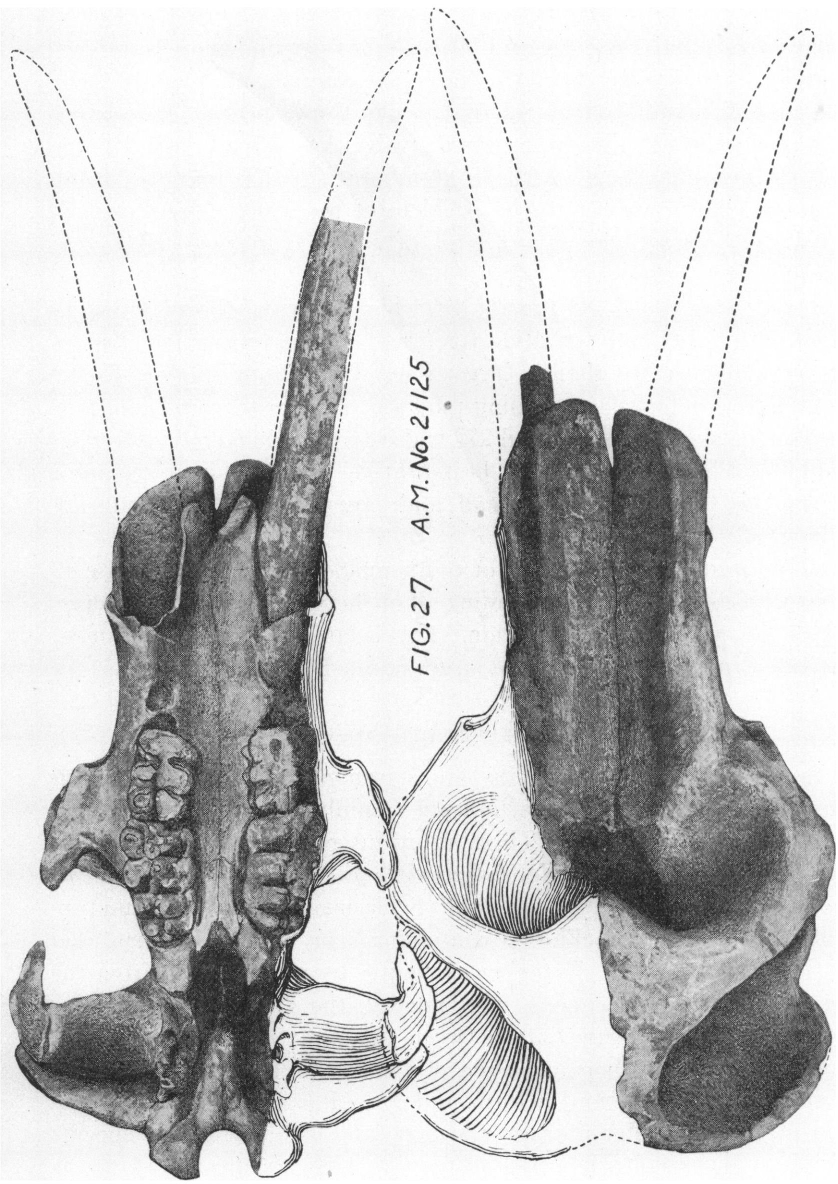

Fig. 27. *Trilophodon* (*Serridentinus*) *pojoaquensis*, new species, skull of paratype. Dorsal and inferior views $\times\frac{1}{10}$.
(See Fig. 1A.) Amer. Mus. 21125. Santa Fé Miocene, New Mexico.

of a palate (Fig. 22B), which are longer anteroposteriorly and shorter transversely than the slightly worn and heavy-proportioned molars of the paratype skull (Figs. 1A and 27), the heavier and more appressed tubercules of this suggesting to a degree the compact p_4 (Figs. 15A and B) of a small mandible here referred to the Cope species. It is hoped that the field-work now in progress, which has already contributed largely to our knowledge of the contemporary fauna, may yet result in a more definite answer to the problem of the limit of size, of symphyseal and cranial elongation, and of molar variation within the individual and the species.

To the Cope type, *T.* (*S.*) *productus*, which agrees in size with Leidy's original material, I here tentatively refer all similar-proportioned specimens of smaller or but slightly larger size. To the new species, *T.* (*S.*) *pojoaquensis*, I refer the remaining material of large to very large size, including the skull (Figs. 1A and 27) and ostensibly longer-symphysised mandibles. The references must be tentative, as a certain overlapping between the two species (of small and large individuals) would be presumed.

For the purpose of the study of tooth replacement, it has been convenient to consider under one heading all of the Santa Fé material representative of the immature dentition. This is later relisted in part under the smaller and in part under the larger Santa Fé species.

Dentition and Tooth Sequence

Among the Santa Fé remains are specimens representing various elements of the dentition and exhibiting a number of consecutive stages in the eruption of the teeth. These afford interesting comparisons with specimens from Texas and Nebraska, with the teeth of *T. angustidens*, figured by Lartet, von Meyer, and Schlesinger, with an immature maxillary specimen from Florida containing a peculiar p^4 in germ, and with the premolars of (?) *T. turicensis*, figures by von Meyer. From the latter the Santa Fé specimens differ greatly, the Florida specimen appearing somewhat intermediate between this and the generalized type represented by the others inclusive of the Santa Fé. The specimens exhibit a certain variation in form and a great variation in size, prophetic of parallel differences in maturity and in evidence of specific distinction. This Santa Fé material may be grouped into five stages as follows:

(1). dp_{2-4}. Mandible fragment with dp_2, dp_3, dp_4 erupting (Amer. Mus. 21113, Figs. 5 and 10). The teeth are in approximately the same stage of eruption as seen in the Eden immature mandible (Amer. Mus. 18226B, Fig. 2), the relative smallness of the dp_3 and dp_4 of the present specimen being paralleled by the dorsoventral lightness of the mandible. No American specimen exhibiting the dp^2 in place or definitely vouching for the occurrence of p^2 is known (see below).

(2). P^3_3 erupted, p^4_4 about to erupt. Mandible with p_3, dp_4, m_1, m_2 (erupting), p_4 in germ, and inferior tusks (Amer. Mus. 21112, Figs. 6, 11, and 24); also a fragment with dp_4 (greatly worn), and m_1 (erupting) (Amer. Mus. 21114, Fig. 14) representing a smaller individual of approximately the same age (but of the size of Amer. Mus. 21113). A nearly similar stage in the replacement of the teeth of the upper jaw is shown by Leidy's Florida maxillary specimen containing p^3, dp^4, p^4 (in germ), and m^1 (fragmental) of both sides of jaw (Nat. Mus. 3064; p^3–p^4, Fig. 20). The p^4 differs widely from the p^4 of Santa Fé.

(3). P^4 in use. Cope's fragmentary maxillary specimen showing (?) p^3 (fragmental, and association doubtful), p^4 (broken), m^1 (slightly worn) and m^2 (erupting) (Nat. Mus. 4179; (?) p^3, Fig. 19B).

(4). P^4 much worn, p_4 lost. Mandible containing p_4 (roots), m_1, m_2 erupting, (m_3 in pouch partly formed), and associated p^4, m^1 and m^2 of upper jaw (Amer. Mus. 21124, Fig. 13, in part). A stage only slightly later than this is represented by the Texan immature skull-mandible specimen (Amer. Mus. 10673) of a somewhat similar but shorter-crowned and shorter-symphysised species (*T.* (*S.*) *serridens*) in which p^4_4 are still in place.

(5). Mature dentition, m^3_3 present, and much worn. Large skull specimen with m^2, and m^3 just erupted (Amer. Mus. 21125, Fig. 1A); moderate-sized and moderate-symphysised neotypic mandibular specimen with m_2–m_3 worn (Amer. Mus. 21111, Fig. 7A); and large and aged mandibular specimen with m_2–m_3 greatly worn (Amer. Mus. 21123, Figs. 1B, 7B, and 13 in part). In the latter the m_2 is seen to lie fully as near to the posterior border of the symphysis and large mental foramen as does p_3 in the immature specimen. (The forward progression of the antero-most tooth of the lower is presumably correlated with that of the upper jaw, and definitely limited by the conformation of the lower jaw and by the roots of the tusks of the upper jaw.)

No specimens representing the dp^2 of the Santa Fé forms or a successor to this tooth are definitely known. The occurrence of p^2 itself must remain problematical. The homology of the very fragmental tooth (Fig. 19A) reported to have been *in situ* with the much broken Santa Fé maxillary specimen, figured by Cope (1877, Pl. LXXI, Figs. 1 and 2, in part) as the "first superior molar," and cited by Lydekker as proving the presence of p^2 in this species, is at best doubtful. So far as observable, the fragment suggests a remnant of a p^3 like that from Heggbach, figured by von Meyer (1867, Pl. III, Figs. 8–10), which seems to represent p^3 rather than the dp^2 suggested by the double alveoli preceding the $p,^3$ p^4 and m^1 of the Heggbach maxillary specimen (Pl. III, Fig. 1). The Cope fragment bears no resemblance to the p^2 germ figured in place by Schlesinger (1917, Pls. II and III).[1]

[1] Two teeth from Nebraska (Amer. Mus. 21451, in part) are interpreted as respectively representing the dp^2 of a large individual, and the same tooth of a much smaller individual.

Dp_2 (Figs. 5, 10, 13A and B), consisting of a small two-rooted cone, is well illustrated in mandible No. 21113. It is smaller-sized relative to dp^3, but otherwise, so far as may be seen, similar to the Simorre tooth figured by Lartet (Pl. XIV, Fig. lb) under *T. angustidens*, though on account of the slightly broken surface it is not known whether it had the same minute anterior accessory cusplets.

The Santa Fé remains include the fragment of a tooth (Fig. 19B), which is indicative of p^3 when compared with the moderate-sized p^3's (Figs. 20A and B) in place, in the Leidy Florida maxillary specimen and p^3 of the Heggbach maxilla. The large "p^3 germ" of the Guntersdorf maxillary fragment apparently represents the misplaced p^4. Dp^3 of the Santa Fé mastodons is as yet unknown. It was presumably much narrowed anteriorly and weakly three-crested as in other trilophodont species. The dp_3 of the smaller Santa Fé form is known by two worn specimens (Figs. 5, 10, 13A and B, and 14C). It is of general characteristic dp_3 form and weakly three-crested, with the anterior valley between the first and second crests broad and diagonally directed, the third crest or heel small and adjoining and slightly inward of the second crest. The Santa Fé tooth is apparently smaller-proportioned, relative to dp_4, and more triangular-shaped than in *T. angustidens* of Simorre, more triangular than in (?) *R.* (*D.*) *edensis*, and more elongate and less quadrilateral than in *M. americanus*. The p_3 (Figs. 6, 11, 15A and B) of mandible (Amer. Mus. 21112) is somewhat abraded anteriorly and posteriorly, so that the presence of the anterior cusplet and slight tuberculate heel shown in Lartet's figure of the smaller p_3 from Simorre (1859, Pl. XIV, Fig. 2B) and that seen in the two also somewhat smaller Florida specimens of Leidy (1896, Pl. IV, Figs. 1, 2, 6, and 7, and Fig. 16 this paper) may not be verified.

The two Santa Fé specimens representing p_4 (one *in situ* in mandible, Amer. Mus. 21112, Figs. 15A and B, the other a detached specimen, Fig. 15C) are tentatively referred to the small *T.* (*Serridentinus*) *productus* species. Both teeth are much smaller, and the former has the two crests considerably less developed and much less separated than in the large species represented by the Texan skull (Amer. Mus. 10673), *T.* (*S.*) *serridens*, and the unworn and equally large p_4 of a mandible fragment from the Nebraska Pliocene (Amer. Mus. 19248). The detached specimen is but slightly different in appearance from the Simorre p_4 figured by Lartet (Pl. XIV, Fig. c') and in form closely resembles the variable-sized p_4's from Laaerberg (figured by Schlesinger) and the above Nebraskan tooth. Another interpretation might consider the detached and slightly larger p_4 as perhaps representing a distinct species from the more compact tooth species, and be taken as evidence of the probable presence of further differences between the dentitions of *T.* (*S.*) *productus* and *T.* (*S.*) *pojoaquensis* when these species are better known.

The Santa Fé p^4 (Fig. 19C) is slightly larger than the broken specimen of the Cope maxilla, somewhat smaller than that of the large Texas *T.* (*S.*) *serridens* and of the Colorado p^4 (representing the type specimen of Copè's *T. angustidens proavus*), but considerably larger than a p^4 (Amer. Mus. 19248J, in part) from Nebraska. All of these teeth, however, are of rather similar bi-crested-tending, four-tuberculated quadrate form, the anterior cusps being more prominent than the posterior and the inner tubercles tending to form trefoils as in the figures teeth from Simorre, and from Heggbach (the m^1 of this last being only very slightly shorter than the m^1 of Cope's maxilla). The Santa Fé p^4 is, however, quite different from that of the Florida maxilla (Fig. 20A and B) which seems intermediate between thè former and that figured by von Meyer under *M. turicensis* from Elgg (Pl. V, Fig. 1). In the Florida specimens the anterior and posterior inner borders are strongly constricted, the anterior tubercles prominent, the posterior ridge very weakly developed, the trefoils being quite rudimentary and the cusps and ridges minutely multi-tuberculate. In the Elgg specimen the transverse crests are serrate and sharply defined and without trefoils. (The slightly worn Simorre p^4 figured by Lartet, Pl. XIV, Fig. 4, may have belonged to a different individual from the unworn p^3. The same p^4 is largely functionless, and normally erupts in the mastodons, as seen in Santa Fé material, after p^3 as in other mammals.)

The three-crested first molars are somewhat larger than the three-crested last milk molars; the second molars are considerably larger than the first molars, m^3 is much longer than m^2, and m_3 is apparently slightly longer than its broader homologue, m^3. (See discussion and hypothetical percentages preceding measurement table.)[1]

Summary.—The small conical antero-most tooth of the immature mandible apparently lacks a known predecessor or successor and is here (as in *Phiomia*) considered to represent dp_2. Dp^2 is unrepresented in our material. It presumably conformed to the tooth seen in place in the Guntersdorf maxilla (Schlesinger, 1917, Pls. II and III). Whether a p^2 was developed as in *Phiomia* and as figured by Schlesinger (*loc. cit.*)

[1] Viewed externally, m^3 has three roots: a single antero-inner, a double antero-outer and a combined main posterior; m_3, two roots: an anterior transverse and compound posterior; m^2, three roots: a narrow antero-inner, a broader outer and a transverse posterior; m_2 two roots: an anterior and a compound posterior.

is unknown. The somewhat triangular, three-crested-tending, and widely divergent-rooted dp_3 is vertically replaced by a noticeably smaller, more simplified, and compactly rooted p_3, and the three-crested dp_4 by a similarly smaller and simplified p_4. Dp^3, presumably weakly three-crested, is as yet unknown; p^3 is oviform; dp_4 is three-crested; and p^4 is smaller than its milk homologue, quadriform and weakly bi-crested. P^3_3 and p^4_4 develop near the inferior ramal surface immediately beneath, and with growth become locked between the roots of their respective milk predecessors. During eruption they are crowded forward along with the partially absorbed roots of their respective homologues through the eruption and forward progression of the first and second molars, so that the p^4_4, which erupt sometime subsequent to p^3_3, before being shed, come to occupy a position actually anterior to that occupied by their deciduous predecessors. Such progression of p^4_4 in respect to dp^4_4, hitherto unexplained, has doubtless occasioned the statement "that dp_4, unlike the two anterior teeth, has no permanent successor." In the forward progression of the molars, m^1_1 push forward and replace the premolars and are in turn replaced by m^2_2, which, as their anterior roots become absorbed, continue to be crowded forward by m^3_3 and finally come to overhang the alveolar border in advance of the position once occupied by the antero-most milk molars and premolars. Thus, while the portion of the mandible anterior to the posterior border of the symphysis, already greatly elongate in immaturity with growth, becomes even more elongate, the unoccupied alveolar border posterior to the same point through the forward progression of the teeth may actually become shorter.

In résumé the tooth ridge formula of the Santa Fé forms may be shown as $dp\frac{(?1\frac{1}{2}).\text{–}2\frac{3}{4}.3}{1\frac{1}{2}.\text{–}2\frac{3}{4}.3}$, $p\frac{(?)\text{–}1\frac{1}{2}.1\frac{3}{4}}{1\frac{1}{2}.1\frac{3}{4}}$, $m\frac{3.3.4}{3.3.4}$, in these forms each milk molar is to a certain degree prophetic of the permanent tooth of the next posterior position; the two posterior milk molars (at least) of each jaw are replaced vertically by smaller and simpler true premolars; m^3 may be much more elongate than m^2, m_3 is presumably slightly longer than m^3, and the cheek-tooth series in advanced maturity consists alone of the elongate m^2_2–m^3_3.

MEASUREMENTS.—The following table gives the estimated length of teeth and symphysis of various Santa Fé specimens arranged from left to right in ascending order from the smallest to the largest; and in adjoining columns, for the purpose of comparison, similar measurements of two Clarendon skulls and jaws, the Shawangunk mastodon skull, and a long-symphysised tetralophodon mandible from Kansas. Measurements of

MEASUREMENTS AND ESTIMATED MEASUREMENTS OF TEETH, ARRANGED ACCORDING TO SIZE.
IMMATURE TRILOPHODONT MASTODONS FROM NEW MEXICO, HEGGBACH, SIMORRE, SANSAN, AND FLORIDA
(*E. leidii* and referred specimens)
(Measurements are per explanatory paragraph, page 154)

	m^3_3	m^2_2	m^1_1	p^4_4	p^3_3	dp^4_4	dp^3_3	dp^2_2
Amer. Mus. 21119 (New Mexico)	$\underline{[125]}$ 136	$\underline{[89]}$ [90]						
Nat. Mus. 3057–8.(?) *T.* (*S.*) *leidii* (Florida)					$\overline{26\frac{1}{2}}$			
Nat. Mus. 3062 *T.* (*S.*) *leidii* (Florida)					$\underline{32\frac{1}{2}}$			
Amer. Mus. 21114 (New Mexico)			$\overline{74}$			$\overline{\text{(broken)}}$		
Simorre specimen (fig'd Lartet, Pl. XIV, Fig. 4)			$\overline{81}$	$\overline{40}$	$\overline{25}$	$\overline{59}$	$\overline{33}$	
Sansan cast Amer. Mus. (Warren Coll.)						$\overline{59}$	$\overline{32}$	$\overline{11}$
Heggbach palate (fig'd von Meyer)			$\underline{76}$	46	$\underline{34}$			
Nat. Mus. 3064, Leidy maxilla, (?) *T.* (*S.*) *leidii* (Florida)				$\underline{46}$ (germ)	$\underline{36}$	$\underline{74}$		
Amer. Mus. 21113 (New Mexico)						$\overline{78}$	$\overline{42}$	$\overline{(10)}$
Nat. Mus. 4179, Cope maxilla (New Mexico)		116	(90)	(45)	(?)			
Santa Fé, Cope type mandible (New Mexico)	$\overline{155}$							
Amer. Mus. 21112, neotype (New Mexico)		[120] germ	$\overline{86}$	$\overline{45}$	$\overline{27+}$	$\overline{(67+)}$ broken		
Amer. Mus. 21124D, p4 (New Mexico)				50				
Amer. Mus. 21124 (New Mexico)	$\underline{[191]}$ [204] germ	$\underline{136}$ 136	$\underline{100}$ (broken)	$\underline{(50+)}$ (roots)				

COMPARATIVE MEASUREMENTS *Trilophodon* (*Serridentinus*) species

Skull	Santa Fé Miocene, New Mexico										Clarendon, Texas		*Mastodon americanus*
	T. (*S.*) *productus* Cope					*T.* (*S.*) *pojoaquensis*, n. sp.					*cimarronis* Cope	*serridens* (Cope)	
	Small broken ramus. Amer. Mus. 21119, M_3, Fig. 22D	Cotypic immature maxilla. Nat. Mus. 4179, P^4, Fig. 19A	Neotypic mandible. Amer. Mus. 21111, Fig. 12	Cope type mandible. Nat. Mus. 4179	Tentatively referred m^3. Amer. Mus. 21116, Fig. 22C	Skull. Amer. Mus. 21125, Figs. 1A and 27	Mature mandible. Amer. Mus. 21123, Figs. 1B and 13 (in part)	Amer. Mus. 21118, Fig. 22B	Amer. Mus. 21124, Fig. 12 (in part)	Type specimen. Amer. Mus. 21115, Fig. 26	Referred skull and jaws. Amer. Mus. 10582	Referred skull and jaws. Amer. Mus. 10673	Shawangunk skull and jaws. Amer. Mus.
Infra-orbital foramen to auditory meatus						406					404	(425)	?460
Condyle to incisive border						920					770–790	830	1,100
Condyle to post. nares (m^3)						330					300	360	397
Post. nares to incisive border						610				680	465	490	710
Height cranium at occipital plate						580					(cracked)	(crushed)	540
Breadth cranium at occipital plate						(640)					(520)	(640)	800
Length m^3	[125]	[140]	[141]	[143]	153	172	[175]	185	[191]	197	147	[169]	155
Length m^2	[105]	116	[120]	[120]		122+	[125]	(132)	136	[140]	123	142	103
Length m^1		(90)							(100)		(85)	100	88
Length p^4		(45)							(50+)			57	
$M^3 = m^2 + - (m^2 x\%)$ %			say 20%			40%					19%		50%

Mandible	Santa Fé Miocene, New Mexico											Clarendon, Texas		*Mastodon americanus*	*Tetrabelodon giganteus* Osborn, S. Dakota
	T. (*S.*) *productus* Cope					*T.* (*S.*) *pojoaquensis*, n. sp.						*cimarronis* Cope	*serridens* (Cope)		
	Small broken ramus. Amer. Mus. 21119, M_3, Fig. 22D	Immature mandible. Amer. Mus. 21112, Fig. 11	Neotypic mandible. Amer. Mus. 21111, Fig. 12	Cope type mandible. Nat. Mus. 4179	Tentatively referred m^3. Amer. Mus. 21116, Fig. 22C	Skull. Amer. Mus. 21125, Figs. 1A and 27	Mature mandible. Amer. Mus. 21123, Figs. 1B and 13 (in part)	Amer. Mus. 21118, Fig. 22B	Amer. Mus. 21124, Fig. 12 (in part)	Type specimen. Amer. Mus. 21115, Fig. 26	Amer. Mus. 21122A	Referred skull and jaws. Amer. Mus. 10582	Referred skull and jaws. Amer. Mus. 10673	Shawangunk skull and jaws. Amer. Mus.	Amer. Mus. 17735
Condyle to incisive border...			830				1050 (to break)					900	950		1,560
Condyle to P. S..............			570				770		(510–620)			620	660		830
M. I. S. to P. S.............		248	345				450		345			365	395		500
P. S. to incisive border......	[244]	175	274	274			320 to break		320 to break	[525]		287	315		750
$\frac{M_3}{\text{Symphysis}}$................			56%				say 40%					57%			
Depth horizontal ramus below middle of m_2............	124		136	133			170		115			135	ant. m_2 140		220
Length m_3................	136	[150]	153	155	[168]	[185]	189	[203]	[204] (germ)	[210]	226+	165	[187 germ]	155	200 (erupting)
Length m_2................	[105]	(114)	[120]	(110+)		[123]	[126]	[134]	136	[140]		125	142	103	(140)
Length m_1................		87							(87+ + broken)			(alv.)	(100)	[88]	(150)
Length p_4................									(roots)				59		

mastodon teeth as usually taken are apt to be highly unsatisfactory for the purpose of comparison, on account of no allowance being made for the state of wear, the tooth ever becoming shorter from the time of eruption to time of shedding (through continuous attrition with its neighbors during progression from the back to front of the jaw). The measurements here given are, therefore, the estimated lengths of the moderately abraded teeth, except in the case of those measurements in parentheses, which are the apparent lengths of broken or greatly worn specimens, and of the measurements in brackets, which are hypothetical figures based upon the proportions existing between the associated teeth in other supposedly similar specimens from the same locality (as indicated).

Trilophodon (Serridentinus) productus Cope 1874

Mastodon species, Leidy, 1872, Proc. Acad. Nat. Sci. Phila. XXIV, p. 142.

Mastodon obscurus and *M. shepardi* Leidy (in part), 1873, Rept. U. S. Geol. Surv. (Hayden), I, pp. 235, 330, Pl. XXII, Figs. 1–4.

Mastodon productus Cope, 1874, Proc. Acad. Nat. Sci. Phila., XXVI, p. 221; 1875, Amer. Journ. Sci., (3) IX, p. 222 (short note); 1875, Ann. Rept. Chief of Engineers, Append. LL, Gl., p. 72; 1877, U. S. Geogr. Surv. West of 100th Meridian (Wheeler), IV, pp. 24, 306, Pls. LXX–LXXII; 1884, Amer. Nat., XVIII, p. 524. Lydekker, 1886, Catalogue of the Fossil Mammalia in the British Museum, Part IV, p.x.

Tetrabelodon productus Cope, 1884, Proc. Amer. Philos. Soc., XXII, p. 5 (1885); 1889, Amer. Nat., XXIII, pp. 195, 204 ("3 pms"); 1893, Fourth Ann. Rept. Geol. Surv. Texas, p. 58 (mentions); 1893, Proc. Acad. Nat. Sci. Phila., XLV, p. 203 ("Leidy, 1873, wrong in referring N. Mex. specimens to *shepardi*"). Matthew, 1899, Bull. Amer. Mus. Nat. Hist., XII, p. 68. Trouessart, 1905, Catalogus Mammalium, Quinquennale Supp., Anno. 1904, p. 600.

Mammut productum Cope, Hay, 1902, U. S. Geol. Surv. Bull. No. 179, p. 711.

Trilophodon (=*Gomphotherium*) *productus* (in part), Matthew, 1909, U. S. Geol. Surv., Bull. No. 361, p. 116. Osborn, 1910, Age of Mammals, p. 299 (in part). Zittel, 1923, Grundzüge der Paleontologie, p. 630.

Type Specimen, Described by Cope, 1874.—A mandible containing the m_2 (broken), m_3 (erupting) and tusk of both sides; symphysis entire but lacking contact with rami; coronoid and angular processes missing. From Santa Fé, New Mexico. Figured by Cope, 1877, Pl. LXX, Figs. 1–3; Pl. LXXI, Fig. 3. Nat. Mus. Coll., cast Amer. Mus.

Referred Material from Santa Fé Area

Material Approximating Type Specimen in Size

Mature Specimens

Three fragments of a lower jaw, including a portion of the right ramus containing m_3 (broken) and two sections of an enormously prolonged symphysis, all apparently of one individual; and portions of a vertebra and of a rib. Presented to the Smithsonian Institution by Governor Arny of New Mexico. Nat. Mus. Coll. Figured and described by Leidy under *M. obscurus* and *shepardi* (1873, Pl. XXII).

Neotypic mandible containing m_2, m_3 (considerably worn), and tusks of both sides. Amer. Mus. 21111, Figs. 7A and 12. (D.1)

IMMATURE SPECIMENS

Cope maxillary fragments with (?) p^3 (broken), p^4 (broken), m^1, and m^2 (erupting). Figured by Cope, 1877, Pl. LXXI, Figs. 1 and 2. Nat. Mus. 4179. This paper (?) p^3, Fig. 19A.

Mandible containing p_3, dp_4, p_4 (germ), m_1, and m_2 (erupting). Amer. Mus. 21112, Figs. 6, 11, and 24. (D.1)

P_4 (germ. More slender, shorter-crowned, and less compact than p_4, Amer. Mus. 21112). Amer. Mus. 21124B, Fig. =15c. (D.2)

MATERIAL OF (12 PER CENT) SMALLER SIZE THAN TYPE

MATURE SPECIMEN

Portion of right ramus containing broken roots of m_2, and worn and somewhat broken m_3. Amer. Mus. 21119, Fig. 22D. (D.2)

IMMATURE SPECIMENS

Mandibular portion with dp_2, dp_3 and dp_4 (erupting) of right side. Amer. Mus. 21113, Figs. 13A and B. (D. 1)

Dp_3 (worn), left. Amer. Mus. 21121, Fig. 15C (reversed). (D. 2)

Dp_4 (worn)–m_1, right, *in situ*, Amer. Mus. 21114, Figs. 14A and B.

VARIOUS SPECIMENS BUT TENTATIVELY REFERRED

M^3 right, moderately worn. Amer. Mus. 21116.

Fragment of palate with posterior portions of m^3. Amer. Mus. 21120.

M_3, anterior one-third missing. Amer. Mus. 21117A.

Molar fragment. Amer. Mus. 21117B.

Large immature superior tusk with band and two considerably smaller specimens. Amer. Mus. 21122D, B and C.

Skeletal elements, including an ulna-radius measuring 485 mm., and a tibia measuring 405 mm.

CHARACTERS.—Length of mandibular symphysis less than alveolar distance (page 157), and see résumé under Dentition and Tooth Sequence, page 154, and also characters under *T.* (*S.*) *pojoaquensis*, page 161.

TYPE DESCRIPTION OF COPE (1874).—". . . the posterior inferior molar supports five transverse series of tubercles, of which the posterior is less developed than the others. Each series is composed of two cusps of a conic form which are separated deeply from each other, and are not united at the base so as to become confluent on attrition. The cones of the outer side support one or two accessory tubercles on a line with their inner or median face, so that the transverse section of a worn tooth with the two accessory tubercles is that of a trefoil with the lobes inward. The penultimate molar in the same jaw supports three transverse series. The symphysis is elongated, depressed, and subspatulate; its proximal half is excavated, the distal half flattened. Two tusks project from the extremities; they are short, obtuse, and flattened on the inner side. . ."

DESCRIPTION OF LEIDY'S SPECIMENS, LEIDY (1873).—". . . The lower-jaw fragments appear all to have pertained to the same specimen . . . the last molar tooth

. . . has lost the portion back of the third ridge of the crown. The portion preserved sufficiently resembles in its construction the corresponding portion of the California [Contra Costa County] tooth above described to belong to the same species, which I suspect actually to be the case. It also resembles more nearly the corresponding portion of the same tooth of *M. augustidens* of Europe than it does that of the *M. americanus*. The other jaw-fragments . . . form together the anterior extremity of the enormously prolonged symphysis, like that of *M. augustidens*. . . . The tusks are slightly compressed cylindrical, and curved in their course . . . they are unprovided with enamel. . . "

DISCUSSION.—A newly secured mandible (Amer. Mus. 21111, Figs. 7 and 12), containing m_2, m_3, and tusks of both sides, represents a mature individual of approximately the same size proportions and age as the much less well-preserved Cope type specimen. I consider the mandible as representing a neotype of *T.* (*Serridentinus*) *productus* Cope. The m_2 is much worn, the anterior root being nearly reabsorbed. This tooth is seen to be nearer the posterior border of the symphysis and to the larger mental foramina than is dp_3 of the immature specimen (Amer. Mus. 21112, Figs. 6 and 11). The m_3 is over 20 per cent smaller than the m_3 of the longer-symphysised mandible of an individual referred to *T.* (*Serridentinus pojoaquensis*, new species (Amer. Mus. 21123, over 35 per cent smaller than the hypothetical m_3 of the type specimen of the latter species, and some 12 per cent longer than the smallest m_3, that of a fragmental mandible (Amer. Mus. 21119, Fig. 13), here referred to *T.* (*S.*) *productus* (see table).

The immature material grouped under this species has already been considered in detail in the preceding discussion under "Tooth Sequence." It suggests individuals whose immature dentition would approximate that of the type specimen in size, and others that in maturity would be of dimensions considerably inferior to the type. The Cope immature maxillary cotype is of the former category. The p^4 is some 14 per cent smaller than the Texan p^4 of American Museum specimen 10673 (the anteroposterior diameter of m^2_2 of the latter equaling that of immature American Museum specimen 21124 referred to *T.* (*S.*) *pojoaquensis*, n. sp.). American Museum specimen 21113 (Figs. 13A and B) is of the second category, and smaller than the immature cotype. This is at once evidenced in a comparison of the dp_4 (erupting) and the dp_4 (though much worn) of mandible American Museum 21112, the p_4 (Figs. 15A and B) of the latter specimen being of proportionate size to the Cope immature maxillary p^4 (for comparison of the Santa Fé with the Texas and Florida material, see under *T.* (*Serridentinus*) *pojoaquensis*).

Trilophodon (Serridentinus) pojoaquensis, new species

TYPE SPECIMEN.—Fragment of skull containing m^2–m^3 of left side, and both tusks. Amer. Mus. 21115, Figs. 26 and 22A. Collected in Santa Fé deposit by Messrs. Simpson and Falkenbach. (D.1)

REFERRED MATERIAL COLLECTED IN SANTA FÉ DEPOSIT BY MR. JOSEPH RAK

MATERIAL EQUALING TYPE IN SIZE

M_3, of great size, surface of crown missing. Amer. Mus. 21122A.

MATERIAL SOMEWHAT SMALLER THAN TYPE:

MATURE SPECIMENS

Well-preserved skull containing m^2–m^3 (slightly worn) of both sides, and tusk of left side of jaw. Pojoaque area. Amer. Mus. 21125, Figs. 1A and 27. (D. 2)

Mandible containing m_2–m_3 greatly worn, anterior end of symphysis missing. Amer. Mus. 21123, Figs. 7B and (in part) 13. (D.1 "P.B.")

Partial ramus of right mandible containing m_2 and m_3 (broken). Amer. Mus. 21118B. (D.2)

Palate with m^2 (broken) and m^3 (unworn) of both sides of jaw. Amer. Mus. 21118, Figs. 22B and C. (D.2)

M_3 (unworn) in fragment. Amer. Mus. 21118A.

Right femur measuring 810 mm. Amer. Mus 21126. (D.1 "P.B.")

IMMATURE SPECIMENS

Mandible containing p_4 (roots), m_1 and m_2 (erupting) of left and m_1–m_2 (erupting) of right side, anterior end of symphysis broken, and associated p^4–m^2 of right side. Amer. Mus. 21124, Fig. 13 (in part). (D.3 "S.C.1–2")

P^4 (broken). Amer. Mus. 21124D, Fig. 19C. (D.2)

(?) P^3 fragment. Amer. Mus. 21124C, Fig. 19B. (D.2)

Dp^4 right (moderately worn), Amer. Mus. 21124E. (D.2)

CHARACTERS.—(As seen in type specimen) huge size as compared to *T.* (*S.*) *productus* Cope; tooth crowns high, main tubercles large and resultingly crowded, three-crested intermediate molars wearing to single trefoils, four-crested last molars with slight tuberculate heels, and m^3 greatly elongate relative to m^2; mature cheek-tooth series consisting of m^2_2–m^3_3; large downwardly directed superior tusks with broad band of enamel on outer surface; (as seen in paratypes), cranium extremely high dorso-ventrally and compressed anteroposteriorly, anterior maxillary pre-maxillary region greatly produced, infra-orbital foramina lying approximately mid-way between basal plate and incisive border; mandible with small dorsoventrally compressed tusks; symphyseal length ostensibly equaling or exceeding alveolar-distance,[1] being more elongate, and the gutter narrower-proportioned than in *T.* (*S.*) *productus*.

DESCRIPTION OF TYPE SPECIMEN (AMER. MUS. 21115, FIG. 26).—The specimen exhibits a portion of the left maxilla and adjacent region containing m^2–m^3 (cracked) and tusks of large size. The m^3, which is slightly worn, in anteroposterior diameter exceeds by 40 per cent the estimated length of the hypothetical m^3 of the type of

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[1] "Alveolar-distance," in contradistinction to alveolar-length, to equal the distance between protuberance at mid-inner corner of alveolar pouch and posterior border of symphysis.

T. (*S.*) *productus*. Except for its much greater size and perhaps more massive tubercular arrangement, the tooth broadly resembles the last molars referred to the latter species. This molar, and a broken m_3 (Amer. Mus. 21122A), that implies a tooth of equal size to that of the huge type specimen of *T.* (*S.*) *floridanus*, represent the largest individuals in the Santa Fé collection. The tusks, which have been much shortened through use, are of heavy triangular-tending cross-section and have on the outer side a broad band of enamel. The particular specimen, on account of its extraordinary size, has been selected for the type of the new species, the much better preserved but somewhat smaller skull being made a paratype.

Description of Paratype.—The right side of the unusually well preserved skull (Amer. Mus. 21125, Figs. 1A and 27) reveals the remarkable height of the posterior cranial area, foreshortening of the cranium proper, and prolongation of the premaxillary-anterior-maxillary area in this form. Double alveoli evince the recent presence of m^1; m^2 is considerably worn; the first crest of m^3 slightly worn. The short nasals, the short true palate, the auditory conduit formed of the post-glenoid and post-tympanic processes of the squamosal and adjoining ex-occipital plate, the short and deeply concave glenoid surface, the short alisphenoid canal, the prominent postorbital region of the frontal and the various foramina (optical, double infra-orbital, lacerum-medium and posterium and condylar, the canal of internal carotid artery, and the stylomastoid foramen) are all of general characteristic proboscidean type. The left side of the specimen is disintegrated and the following areas are either broken or missing: a portion of the median parietal-frontal area; the outer half of the left tusk (the enamel band being indistinguishable) and the right tusk; the postero-extremity of the premaxilla forming the elevated anterior border of the olfactory fossa; a portion of the malar including that which usually projects below the glenoid fossa; the presumably elongate bulla and the prominent pterygoid wings of the alisphenoid. The specimen is further described in the discussion below.

Description of Immature Mandible.—The left ramus contains the roots of p_4, m_1, m_2 erupting, the right ramus m_1 and m_2 erupting, and (within the same matrix and) in definite association the p^4–m^2 of the right side (Amer. Mus. 21124, Fig. 13). The symphysis is somewhat crushed; it is more elongate than in *T.* (*S.*) *productus* (see below); the broken extremity discloses the bases of similar tusks. The unerupted m_2 lies in the alveolar pouch below and just anterior to the mandibular condyle, the tooth axis directed postero-externally and antero-inwardly (through the angulation of the base of the vertical ramus and the alveolar border), the tooth tilted inwardly and forming a wide outwardly opening angle with m^1 (see Fig. 13, page 133).

Discussion of Paratype Skull.—The right side of the paratype skull (Amer. Mus. 21125, Figs. 1A and 27) is beautifully preserved, and displays very completely the characters of the particular specimen, a mature individual with m^1 considerably worn and m^2 coming into wear. The two molars are apparently nearly proportionate in size to those of a large mandible representing a somewhat older individual (Fig. 1B). The diameters of the m^3 and tusk of the paratype are some 15 per cent ess than in the type specimen. The relative proportions between the ast specimens are thus approximately those existing between a small referred mandible (Amer. Mus. 21119), and the neotypic mandible (Amer. Mus. 21111) of *T.* (*S.*) *productus*. The type maxilla may represent the male, the paratype skull the female. The comparison of the Santa Fé paratype with the smaller and better-preserved of the two Texan skulls (*T.* (*S.*) *cimarronis* referred) is of interest in indicating the existence of quite different proportions. In the paratype skull the distance between the infra-orbital foramen and the anterior edge of the premaxilla is approximately the same as that between the infra-orbital foramen and the external auditory meatus. In the considerably smaller skull referred to *T.* (*S.*) *cimarronis*, the latter distance, which, strangely enough, happens to equal that in the New Mexican specimen (which itself is much larger in the teeth and in every other respect), exceeds the distance between the infra-orbital foramen and anterior edge of the premaxilla by 60 per cent.

The specimen is particularly remarkable in the height of the posterior cranial area, an area but seldom found in an uncrushed condition, and in the foreshortening of the cranium proper. The contrast, thus, of the great elevation (through dorsoventral expansion) and anteroposterior contraction (through anteroposterior 'telescoping' of the bones) of the cranium proper, with the marked prolongation of the premaxillary-anterior-maxillary area, is very striking. The general proportions in lateral view are those of recent *Elephas* rather than of Miocene or Pleistocene mastodon, as seen in the much more elongate skulls of *T.* (*S.*) *cimarronis* and *M. americanus*. The posterior edge of m^3 lies opposite to the posterior nares, and the basicranial axis is not strongly angulated as in *Elephas*; the rear of the palate and alveolar palate being thrust downward and forward, but to less degree. A section cut out of the temporal border witnesses a parallel separation of the cancellous tissue and development of air-cells typical of the adult cranium of the elephant. The foreshortening of the cranium proper is very noticeable in the zygoma and basicranial area. This foreshortening is also seen in consideration of the position of the anterior border of the orbit, suborbital foramen, anterior narial opening, and anterior edge of the alveolar border, which, placed much as usual relative to one another, have the appearance of all having been shoved far backward. The constriction of the lofty roof of the cranium through the development of great fossorial areas for attachment of the necessarily powerful muscles of the neck and of the elongated jaw and trunk is carried to an extreme unnoticed heretofore. With the development of the first series of muscles, those of the neck, is correlated the prominent dorsoventrally flattened and transversely concave bed-plate of the exoccipital-supra-occipital region; with that of the masseteric muscles, the deep transverse constriction of the disproportionately foreshortened and dorsoventrally elongated mid-cranial region; and with the probably powerful trunk, the wide gutter of the anteroposteriorly elongate narial-premaxillary trough which extends diagonally forward and downward from below the strong supra-orbital arches and anterior border of the large olfactory fossa and directly forward of the powerful maxillary-dentary battery.

The last molars of the large mandible (Amer. Mus. 21123, Figs. 1B and 13, in part) are so closely proportionate to the last molars of the paratype skull (Amer. Mus. 21125, Figs. 1A and 27) that it is believed that the two specimens represent individuals of approximately the same size, the worn teeth of the mandible, however, showing that the latter was considerably the more aged.

An immature mandible (Amer. Mus. 21124, Fig. 13, in part) indicates an individual that at maturity would apparently measure greater than the above specimen (Amer. Mus. 21123). It is of much the same size as the mandible of the immature and larger of the two Texan skull specimens (Amer. Mus. 10673, *T.* (*S.*) *serridens* referred), the but very slightly shorter $m\frac{2}{2}$ being in the same state of eruption as the $m\frac{2}{2}$ of the latter. The specimen is of great value in permitting a definite comparison of the unused molar of the Santa Fé and Clarendon specimens, the former being observed to be much higher-crowned, provided with bolder tubercles, higher posterior and anterior shelves, and less completely formed and less serrate cross-crests. Compared to the Texan specimen (Amer. Mus. 10673), the mandible measures slightly less (its broken and somewhat distorted condition making measurement difficult), the spout is apparently less depressed and is narrower, the symphysis longer-proportioned (see below), the vertical ramus is narrower anteroposteriorly, the horizontal ramus below the middle of m_2 is approximately the same depth, below m_1 20 mm. less in depth, and the "diastema" is a few millimeters shorter than in the Texan specimen. The teeth of the Santa Fé specimen are slightly more worn, the p_4's are shed, but represented by roots in the right side of the mandible and by the associated p^4. The base of the crowns of $m\frac{2}{2}$ are not far apart in area in the two specimens (the crests being quite unworn in the Texan, and the first crests only slightly worn in the Santa Fé), but the crowns of the New Mexican are noticeably higher, the anteroposterior ledges higher relative to the outer and inner cingula, the main crests less complete and the main tubercles heavier and taller, and the general appearance less minutely multituberculate. The Santa Fé and the two Texan specimens afford interesting evidence of the permanence of p^4 and m^1 relative to p_4 and m_1. In occlusion the anterior crest of the inferior molar falling anterior to that of the opposite upper molar. The anteroposterior diameter of the m_3 of the *T. cimmaronis* skull measures approximately one crest longer (12 per cent) than m^3, a condition that is believed to be approximated in the Santa Fé forms, and that differs from that in Pleistocene *Mastodon* where the last molars of the upper and lower jaw tend to be of equal length. The apparent anteroposterior diameter of m_3, which is incompletely formed, indicates that this would be of the same proportion to m^2 as in the Santa Fé skull, namely, larger-porportioned than in the Texan and *T.* (*S.*) *productus* specimens, but less than in the this way more specialized Pleistocene *Mastodon* (*vide* Warren and Shawangunk skulls). The anteroposterior diameter of m_3, on the other hand, is evidenced to have been shorter relative to the symphysis (see above) than in the more moderate-symphysised Texan species and in *T.* (*S.*) *productus* (type and neotypic mandibles) where it equals 25 per cent of the symphyseal length. The condition of the symphysis of this mandible, unfortunately, renders it impossible to determine the exact proportions. An indication of the symphyseal length is gained by comparison with mandible American Museum 21111, the alveolar-distance (in contradistinction to alveolar-length) being equal in the two specimens, but the remnant of the narrower-porportioned symphysis of the present specimen exceeding in length the wider and terminally expanded symphysis of the latter by 60 mm.

It remains in doubt (as observed above) whether the palate (Amer. Mus. 21118), an m_3 (Amer. Mus. 21118A), and perhaps this immature mandible (Amer. Mus. 21124) may be correctly referred to the new species. The molars of these specimens, particularly as seen in the unworn m^3's of the palate, differ from the type and paratype specimens in the greater length relative to the width and resultingly less crowded condition of the main tubercles.

A large femur tentatively referred to this species measures 810 mm., versus 700 mm. of the femur of the mounted Texan skeleton of *T.* (*S.*) *cimarronis*, 1080 mm. of the longer-limbed Warren mastodon, and 1230 mm. of the Indiana skeleton of *E. columbi*. A relatively small ulna-radius is similarly referred to *T.* (*S.*) *productus*, this measuring 375 mm., versus the estimated 580 mm. of the ulna-radius of the mounted Kansan skeleton, 640 mm. of the Warren mastodon, 890 mm. of the Indiana skeleton, and 510 mm. of an Eden Pliocene specimen.

CERTAIN OTHER *TRILOPHODON* (*SERRIDENTINUS*) SPECIES

The discussion and much-needed revision of those long-symphysised trilophodon species occurring without the confines of the Santa Fé deposit are beyond the province of this paper and will be considered at length in Professor Osborn's forthcoming Memoir on the Proboscidea. It has seemed advisable, however, at this point to give some short account of certain specimens and species frequently referred to throughout these pages, since an understanding of the Santa Fé forms rests so largely on their resemblances to and differences from other forms. These remains witness the wide distribution of variable species that may be tentatively grouped according as to whether their symphyseal elongation is proportionate to, less than, or greater than in *Phiomia*, but which seem to have attained to a somewhat similar stage of tooth replacement. The decision of questions of generic difference and synonymy must await the completion of the comprehensive studies that Professor Osborn is now engaged upon.[1]

Trilophodon (**Serridentinus**) species, Miocene and Pliocene of California

I have been particularly desirous of securing material from the Barstow deposit sufficient for comparison with the Santa Fé so that the resulting evidence might be available with that of other genera for use in the solution of the time relationships of these two "Upper Miocene" faunas and those of the "Mid-Miocene" of Europe. But as yet the only proboscidean remains from Barstow are tooth fragments, which Dr. Merriam has tentatively referred to *Tetrabelodon* (?) sp. (1919, Univ. Cal. Pub. Dept. Geol., XI, p. 471). The presumption is that long-symphysised forms very similar to, if actually separable from, the Santa Fé will yet be found in the Barstow, as such are evidenced as still present in the later Ricardo deposit of the same Mohave basin area, as witnessed both by a specimen figured by Dr. Merriam (1919, Figs. 160 and 161, in which the anteroposterior diameter of m_3 approximates that of the type specimen of *T. productus*), and by the large, long-symphysised mandible exhibited in the Los Angeles Museum of History, Science, and Art.

[1] Osborn, H. F., 1918, Bull. Geol. Soc. Amer., XXIX, pp. 133–137; 1921, *idem*, XXXII, pp. 327–332; and other papers.

Trilophodon (Serridentinus) serridens Cope and **T. (S.) cimarronis** Cope, of Texas

The larger (Amer. Mus. 10673) of the two Clarendon long-symphysised trilophodon skulls, in which the teeth are short-crowned relative to the Santa Fé forms, is placed with *T.* (*S.*) *serridens* Cope, type an intermediate upper molar (Amer. Mus. 14297), (anteroposterior diameter 130 mm.); and the smaller of the two Clarendon skulls (Amer. Mus. 10582) with *T.* (*S.*) *cimarronis* Cope, type an m^3 (anteroposterior diameter 140 mm., figured by Cope, 1893, Pl. III, Figs. 2 and 3), which closely resembles the m^3 (anteroposterior diameter 145 mm.) of this skull. The symphyses of the two mandibles are of moderate length, the tusks of the larger and younger specimen projecting to an unusual degree. The large skull suggests an individual of the size of the widely different *T.* (*S.*) *pojoaquensis* of Santa Fé, and the smaller skull the somewhat smaller material referred to *T.* (*S.*) *productus*. With the Texan species are also tentatively placed remains from Texas referred by Dr. Hay (1925) to *Anancus braziosus* and to *Gomphotherium cimarronis*, through the resemblance of the occurrence and characters noted by this authority. These specimens exhibit a nearly equivalent size variation and include:

A large m_3, Brit. Mus. Coll., with anteroposterior diameter of 225 mm., referred by Lydekker in 1886 to *M. cordillerum*; figured by Hay, 1925, Pl. I.

A fragmentary mandible with m_2 socket and m_3 (broken), from Brazos River, Cameron, estimated length of m_3 being 225 mm.; figured by Hay as type, *A. braziosus*, Pl. II, Fig. 12; Pl. III, Fig. 1.

The remains from Navasota, Texas, referred by the same author to this species (*Gomphotherium cimarronis*) on the evidence of banded upper tusks, long mandibular symphysis with tusks, and typically formed premolars and molars; the same including:

2 p_3's; figured by Hay, 1925, Pl. III, Figs. 2 and 3; 26 mm. and 28 mm.
2 dp_3's; figured by Hay, 1925, Pl. IV, Figs. 1 and 2; 60 mm.
M^2 right; figured by Hay, 1925, Pl. III, Fig. 4; 106 mm.
M^3; figured by Hay, 1925, Pl. III, Fig. 5; 136 mm.
M_3; figured by Hay, 1925, Pl. III, Fig. 6; 136 mm.
Fragment of distal end of mandible and right lower tusk, Fig. 9, tusk diameter 49x37 mm.
Fragments of upper tusks showing enamel banding.

M_3 (Pl. III, Fig. 6), it is interesting to note, approximates in size the smallest m_3 from Santa Fé (Amer. Mus. 21119).

Trilophodon (**Serridentinus**) species, from the Miocene and Lower Pliocene of Nebraska

Dr. Barbour has described and figured in several intensely interesting papers a most remarkable series of skulls and long-symphysised jaws from the deposits of Brown, Cherry and Boyd Counties, Nebraska. These include specimens of widely different symphyseal length (see page 147) and are of unique value in the study of the trilophodon-tetrabelodons of the American Miocene: *T. willistoni* Barbour, 1913, skull and jaw with symphysis of moderate length, exhibiting (?) p_4^4–m_2^2; *T. osborni* Barbour, from Boyd County (1916, Neb. Geol. Surv., IV, Part 30), jaw with long symphysis containing m_2–m_3; *Eubelodon morrilli* Barbour (1913, *op. cit.*, XIV, No. 2) skull and "tuskless" symphysis containing m_3^3; *T. abeli* Barbour, (1925 Bull. Neb. State Mus., I, No. 9) jaw with elongate symphysis containing m_2–m_3, and besides the inferior pair of tusks two alveoli indicative of the recent presence of an additional small pair (see footnote regarding occurrence of two pairs of tusks in immature mandible of *Mastodon americanus*, page 151); *T. lulli* Barbour, from Cherry County (1914, *op. cit.*, IV, Part 14, Bull. 36) mandible with extremely long symphysis, the same approaching or equaling that of *T. angustidens*.

Among a small collection of premolars from the Snake Creek deposit, an unworn p_4 of a mandible fragment (Amer. Mus. 19248) is very large, approximating in size the worn p_4 of the Texas skull referred to *T.* (*S.*) *serridens*, and being 20 per cent larger than a Santa Fé (Amer. Mus. 21124B) specimen tentatively referred to *T.* (*S.*) *productus*, which it otherwise very markedly resembles. An unworn p^4 (Amer. Mus. 19248J, in part) from the same horizon is smaller than the p^4 of the same Texan skull, and is of slightly different form from the p^4's of Santa Fé. The two Snake Creek specimens thus indicate the presence of species of similar range in size to those of Santa Fé. Two other specimens (Amer. Mus. 21451, in part), interpreted as representing a large and a much smaller dp^2, are in further evidence of this range in size. A small specimen (Amer. Mus. 19248J, in part) differs markedly from the above teeth; it presumably represents a (?) p^3 of a more (?) *T. turicensis* type.

Trilophodon proavus Cope of Colorado

The type of this species, a p^4, (figured by Cope, 1889, American Naturalist Fig. 6, and described as a "penultimate milk tooth"), evinces a member of a long-symphysised group of the size of *T.* (*S.*) *serridens* of

Texas, but affords no indication as to whether this belonged to a form whose symphysis was of the upper or lower extreme of elongation.

(?) **Trilophodon (Serridentinus) floridanus** Leidy, and (?) **T. (S.) leidii** new species

The Florida species, based on a last lower molar, may be but tentatively referred to this genus. This and other large molars are very suggestive of those of the Santa Fé and Texan specimens, but the molars of widely differing mastodons are frequently of generalized trilophodon character, and the p^4 referred, of the Florida remains, differs markedly from that of all the above forms. The condition of the symphysis is yet unknown. The type (Nat. Mus. 3083) of *T.* (*S.*) *floridanus* Leidy is a large m_3 with an anteroposterior diameter of 225 mm., the tooth thus only slightly exceeding in length the largest of the Santa Fé teeth.

This Florida specimen represents an individual differing as conspicuously in size from that prophesied by the Leidy immature maxillary specimen (containing p^3, p^4 in germ beneath dp^4, and m^1 (broken), Nat. Mus. 3064, figured Leidy, 1896, Pl. IV, this paper, in part, Figs. 20A to C), as do the larger Santa Fé specimens from the type of *T.* (*S.*) *productus.* I, therefore, suggest that this maxillary specimen, indicative of a smaller Florida race, be taken as the type of a new species, (?) *T.* (*S.*) *leidii.* The specimen is of unusual interest, not only in displaying associated p^3 and p^4, the vertical replacement of dp^4, and the former presence of a long-rooted tooth (? dp^2) anterior to p^3, but as well in the peculiar form of p^4 (Figs. 16A-D; 20A-C), and its position below the anteroinner corner of dp^4, which suggests that the tooth would erupt out of the normal position (and perhaps as in *T. turicensis*).

THE DEPRESSED-BEAKED MASTODON OF THE EDEN LOWER PLIOCENE. CALIFORNIA

(?) **Rhynchotherium (Dibelodon) edensis** Frick

I described, in 1921, a maxillary specimen containing the last molars and fragmental penultimate molar, the proximal portions of a pair of presumably associated tusks, and certain referred teeth and skeletal elements from the Eden Pliocene of California, as a new subspecies, *Trilophodon shephardi edensis*, noting the resemblance of the m_3 to that of *Mastodon shepardi* Leidy of California. It will be recalled that Leidy, in 1871, founded *M. shepardi* (indefinitely distinguished from *M.*

obscurus Leidy, alone represented by a Maryland intermediate molar) on a superior tusk fragment from Stanislaus County, not on the as well described jaw fragment with m_3 (and reported tusks) from Contra Costa County, which, in 1872 and subsequently, he apparently considered as representing the type. It will be recalled that Cope, in 1884, placed with the Leidy *M. shepardi* material a Mexican mandibular specimen with short decurved toothless symphysis and an "associated" section of an enamel-banded upper tusk, and transferred the conjoint species to a new genus, *Dibelodon*, characterized as ". . . upper tusk with enamel band, lower tusk wanting." It will also be remembered that Cope, in 1893, retransferred this last Mexican specimen to *D. tropicus* and, this time placing with the Leidy California material a mandible from the Blanco containing m_2–m_3 and the proximal portion of a laterally compressed and strongly inferiorly deflected tusk, transferred the Leidy California species, on the characters of this Blanco specimen, to *Tetrabelodon.*

Professor Osborn, in 1922,[1] restudied the Eden material, particularly with respect to the fine pair of tusks embedded in a portion of a premaxilla that represent the tusks of the type description plus their since retrieved distal portions,[2] and transferred the Eden form to *Dibelodon edensis*, observing that ". . . the new cotype (paratype) and the associated material prove that the Eden proboscidean is very close indeed in all its characters to the classic *Mastodon andium* Cuvier of the valley of Tarija, Bolivia, and especially to the skull described by Nordenskiöld in 1903."

Among undescribed material from Eden is an immature mandible with well-developed, downward-deflected beak and tusk, and a slightly more immature maxillary specimen with dentition of apparently corresponding form. The anterior teeth of the two specimens are respectively interpreted as representing dp_2–dp_4 and dp^2–dp^4, cross-sectioning of the jaws attesting to the absence of true premolars in germ. Whether these two new specimens from the Eden type ledge belong to individuals of one and the same species as that represented by the formerly described material, then necessarily a four-tusked and not a two-tusked "*Dibelodon*" form, or whether they represent another trilophodont-tetrabelodont genus must await further evidence. A tusk fragment that shows traces of two enamel bands, versus the one occurring in Eden specimens of the upper tusk, is interpreted as representing that of the

[1] Osborn, H. F., 1922, Amer. Mus. Novit., No. 49.
[2] See Frick, 1921, p. 408, footnote 57.

lower jaw of a more mature individual of the same species. The observed variation in size in the Eden series of last molar teeth is slight (some 11 per cent in three m^3's) and would be readily accounted for by sexual and individual variation. While it may well be that there existed in the Eden Pliocene fauna, as apparently in the Blanco, more than a single species of *Mastodon*, I have felt it preferable, pending the securing of further evidence, to hold the Eden material together under the one previously described species. Though the upper tusks are suggestive of *D. andium*, the m_3 is generally indistinguishable from Leidy's m_3 of Contra Costa County, and the laterally compressed and downwardly directed tusks of the immature mandible are highly suggestive of the Cope Blanco mandible, the upper tusks of which are unknown. I, therefore, tentatively refer the Eden material to *Rhynchotherium* Falconer (genotypic species, *R. tlascalæ* Osborn), to which genus Professor Osborn has now transferred the Blanco specimen.

(?) R. (Dibelodon) edensis Frick, 1921

Trilophodon shepardi edensis Frick, 1921, Univ. Cal. Pub. Dept. Geol., XII, No. 5, p. 405.

Dibelodon edensis Frick, Osborn, 1922, Amer. Mus. Novit., No. 49.

Anancus edensis Frick, Hay, 1923, Pan-American Geol., XXXIX, p. 112.

Type Specimen.—Maxillary portion of skull with both last molars (incompletely erupted), and the right m^2 (broken); and (now considered as a paratype, see below) portions of the premaxilla and upper tusks presumably of the same individual. Collected in the Eden Pliocene, California, by Mr. Joseph Rak. Figured by Frick, 1921, Fig. 160 and Pl. L; Osborn, 1922, Figs. A1 and A2, Univ. Cal. 23501.

Paratype Specimens

(Portions of premaxilla containing complete upper tusks possibly of the same individual as type specimen, Univ. Cal. 24047. Figured by Frick, 1921, Pl. L, Figs. 1 and 2; Osborn, 1922, Figs. A1 and A2).

Two upper molars of right and left sides respectively. Figured by Frick, 1921, Figs. 162 and 164. Univ. Cal. 23503 and 23504.

Lower molar (figured 1921, Fig. 165). Univ. Cal. 23502.

Portion of upper molar, worn (figured 1921, Fig. 161). Univ. Cal. 23505.

Portions of three worn molars. Univ. Cal. 24049, 23507.

Milk molar (figured, 1921, Fig. 163). Univ. Cal. 23506.

Distal portion of small tusk (figured 1921, Fig. 159). Univ. Cal. 24050.

Skeletal fragments.

Referred New Material Collected at Type Locality

Mature Specimens

M_3 left, much worn, Amer. Mus. 18219, Fig. 21B this paper.

M^3 left, unworn, Amer. Mus. 18219D, Figs. 21A and C this paper.

M^3 right, much worn (broken), similar to above, Amer. Mus. 18219E.

Portion of right maxilla with large m^3 (broken) and fragment of m^2, Amer. Mus. 18219A.

Portion of maxillary palate with m^3, and fragment m^2 of right side, Amer. Mus. 18219C.

Fragment of left (?) maxilla with relatively small m^3 (heel broken) and fragment of m^2, Amer. Mus. 18219B.

Portion of left maxilla with parts of dp^4, m^1, Amer. Mus. 18219F, teeth moderately small, maxilla rounded anterior to dp^4, antero-inward narrowness of first crest of dp^4 homologous to narrowness of anterior crest of erupting p^4 in immature maxillary specimen No. 18218.

Intermediate upper molar left (slightly worn), Amer. Mus. 18219G, longer and narrower than slightly broken m^1 in palate No. 18219F.

Three third milk molars greatly worn, exhibiting a considerable size variation and a fourth milk molar greatly worn, Amer. Mus. 18223A-C.

Distal portion of several tusks, Amer. Mus. 18221.

Fragment of an inferior tusk with enamel on two sides, Amer. Mus. 18221Z.

Ulna and partial radius of moderately long and heavy proportions, Amer. Mus. 18350.

Etc. limb and vertebra portions and fragments, Amer. Mus. 18222.

Immature Specimens

Mandible specimen consisting of a left ramus with dp_2, dp_3, dp_4, and m_1 in germ; and right ramus with alveolus dp_2, dp_3, and dp_4 erupting, Amer. Mus. 18216B, Figs. 2 and 8.

A fragment of mandible with dp_3 left (only slightly worn) and portion of alveolus dp_2, Amer. Mus. 18216A, Figs. 3 and 9.

A left maxilla with dp^2, dp^3, and dp^4 (broken) erupting, and associated dp^3 right (posterior third missing); specimen showing infra-orbital foramen above anterior edge dp^2, tusk alveolus, and portion of the maxillary palate, representing a somewhat younger individual than the mandibular specimen, Amer. Mus. 18218 (tooth series figured, Fig. 18).

Characters.—Last molars with three main transverse crests and posterior heel, the heel being small and tubercular in m^3, and more prominent and crest-like in m_3 (referred specimen); intermediate teeth with three crests; transverse valleys broad and well defined, though blocked at mid-base; inner lobes of upper and outer lobes of lower teeth, in worn stage, exhibiting trefoils; upper molars broad, inner borders strongly convex; lower molars relatively long and narrow, m_3 inner border slightly concave and outer border convex; tubercular ridges tall and directed forward in both jaws; palate apparently narrow. Upper tusks (possibly of same individual as type specimen) widely divergent and each provided with an enamel band, which by an inward rotation of the tusk axis is carried from the outer border at the base to the inner border at the tip. Mandible (as seen in immature referred specimen): ramus at mental foramen deep, symphyseal region narrow, somewhat elongate, and bent strongly downward; inferior tusks present, laterally compressed and downwardly directed, tips curving slightly forward and upward; permanent premolars apparently never developed, anterior series consisting of dp_2–dp_4; unerupted teeth tending to be minutely tuberculo-serrate. Upper anterior series (as seen in very slightly worn teeth of the referred immature maxillary specimen) consists of dp^2 (somewhat triangular and weakly bilobed), p^3 (tending to be trilobed), and dp^4.

DISCUSSION.—The referred Eden m_3 (Amer. Mus. 18219, Fig. 21B), as previously noted, resembles the corresponding referred element of the indefinitely known *Rhynchotherium* (*Mastodon*) *shepardi* Leidy[1] of California, in size, proportions, general development of the tubercles, and the peculiar inward position of the trefoils. The specimen together with the referred immature mandible (as noted below) suggests such a form as that represented by Cope's *R.* (*Dibelodon*) *shepardi* mandible from the Blanco and, to a more limited degree, by Osborn's neotypic mandible of the genotypic Mexican species (*R. tlascalæ* Cope, Osborn) of *Rhynchotherium*, to which genus Professor Osborn also refers *T. shepardi* Leidy of California. (It must be noted, however, that the superior tusks of the Eden paratype widely differ from those of a supposed rhynchothere from Kansas, *R. euhyphodon* Cope. The distal end of a peculiar tusk (No. 18211Z), which, as hypothetically orientated, is compressed laterally and has a heavy enamel band on the outer and a light band on the inner face, and a considerably worn inferior and slightly worn superior surface is believed to further evidence the presence of inferior tusks in the Eden adult. Though the Eden molars generally resemble those of trilophodont forms, the m_3 is seen to differ from that of *Trilophodon* (*Serridentinus*) in its slighter tubercular heel, and in its general relative shortness, the brachydont character being especially evident in comparison of the m^3's (Figs. 21A and C versus 22B). The Eden immature mandible also markedly differs from that of the latter trilophodont in its relatively deep symphysis, depressed and much less elongated beak, laterally compressed and depressed (inferior) tusks, and the apparent total absence of vertical successors to the deciduous molars. The Eden species in its superior tusks suggests the Pleistocene *Mastodon andium* Cuvier, as pointed out by Professor Osborn; but in its mandible, as seen in a comparison of the immature referred Eden specimen with the immature specimens figured by Dr. Boule, it differs widely from the short, elephantoid and typically tuskless mandible of the latter.

A comparison of the (?) *R.* (*Dibelodon*) *edensis* immature mandible (Figs. 2 and 2B) with the two mastodon extremes represented by the immature and mature *Trilophodon* (*Serridentinus*) specimens from the

[1] Leidy, 1873, p. 232, states that a small photograph sent to him by the collector of this specimen ". . . exhibits the lower jaw . . . with straight tusks projecting with an upward direction [the tusks appearing] to be as long as the jaw was in its complete condition." In case the Leidy m_3 actually belonged to the specimen of the photograph, it would evidently belong to a long-symphysis form and not to such a mandible as Cope's Blanco specimen.

Santa Fé Miocene (Figs. 6 and 7A) and the immature and mature mandibles of the Boule Tarija and Warren (Fig. 4A) Pleistocene forms, indicates that the Eden Pliocene specimen represents a form quite different from either. My own hypothesis is that in maturity the present m_1 of the Eden mandible, crowded forward by m_2 and m_3, would advance to a position approximately equal or possibly anterior to that now occupied by dp_2 (see Fig. 1); that this horizontal progression of the molars in the growing jaw might be attended by a slight forward and downward progression of the tusk and pulp cavity with but negligible interference of roots of molar and tusk; and that the mature Eden mandible, thus differing as widely as the immature mandible from the trilophodons of Santa Fé, from *Mastodon* (*Dibelodon*) *andium* of Tarija and *Mastodon americanus*, would to a degree approximate that of *Rhynchotherium shepardi* of the Blanco Pliocene. The final substantiation of such hypothesis, however, in lieu of more direct evidence, must await the finding of the immature mandibular dentitions of some known species of *Rhynchotherium*, or of both the immature and mature mandibles of an ancestral rhynchothere form such as that which may yet be found to have existed along with the trilophodon forms of the Miocene of Santa Fé.

As the immature mandibular Eden specimen (Figs. 2 and 8), Amer. Mus. 18216B, containing dp_2, dp_3, dp_4 (erupting), m_1 (in germ), and a small inferior tusk, represents a stage of tooth eruption almost identical with that of the widely different *Trilophodon* (*Serridentinus*) specimens (Figs. 5 and 10), Amer. Mus. 21113, a comparison of the two is of unusual interest:

A. The anterior edge of dp_2 lies directly superior to the posterior border of the pulp cavity of the tusk and to the mental foramen in (?) *R.* (*D.*) *edensis*, versus far posterior to both in *Trilophodon* (*S.*) *productus*, in which the pulp cavity lies wholly forward of the posterior border of the symphysis.

B. The considerable depth of the ramus opposite and anterior to the mental foramen and the prominent depressed beak in *R.* (*D.*) *edensis*, versus the relative shallowness of the ramus and horizontal elongation of the symphysis in *T.* (*S.*) *productus*.

C. The apparent absence of even the germs of replacement teeth (see cross-section from inner side, Fig. 2A) in *R.* (*D.*) *edensis*, versus p_3 and p_4 present and well developed beneath their deciduous predecessors in the *T.* (*S.*) *productus* individual of apparent similar age.

D. The tusks laterally compressed, lying on edge, and directed downward and curving slightly forward and upward and banded with enamel in *R.* (*D.*) *edensis*, versus dorsoventrally compressed and lying much more nearly in line with the posterior portion of the ramus and without enamel band in *T.* (*S.*) *productus*.

Measurements of Eden Mastodons

	Mandible, Amer. Mus. 18216B, Fig. 8	dp_3, slightly worn, Amer. Mus. 18216A, Fig. 9	Maxilla, Amer. Mus. 18218, Fig. 18	Type maxilla Univ. Cal. 23501 (1921, Fig. 160)	Separate teeth Amer. Mus. 18219D, Fig. 21A	Maxillary fragment, Amer. Mus. 18219F	Amer. Mus. 18219, Fig. 21B	*R. shepardi* Leidy, Contra Costa Co., Cal. worn m_3, cast Amer. Mus. 12388
dp^2			35.5x(28)					
dp^3			49x41(broken)					
dp_2	(25x17)							
dp_3	(50x36.5)	51.5x34						
dp_4	89x(51) 86x55 rt					(87)		
		Amer. Mus. 18219G	Amer. Mus. 18219B					
m_1	(in germ)	119				(113)x81(2d C)		
						Amer. Mus. 18219C		
m^3			146x80(2d C)	150x42(1st C) 42(2d C)	154x85(1st C) 84(3d C)	(163)		
m_3							162x68(2d C)	162x71(2d C)

In conclusion, the small antero-most and fragmental tooth in the immature mandible is taken to represent dp_2, the antero-most and slightly larger tooth in the maxillary specimen dp^2, and the small inferior tusks to represent the permanent pair. Dp_3 and dp_4 are of much the form common to these teeth in *M. americanus*, *M. andium*, and in long-symphysised trilophodonts.[1] These milk premolars, however, unlike in the latter trilophodonts, have no vertical successors and are replaced alone horizontally. Hypothetically, in the forward progression of the molars, m_1 and m_2 would in turn come to occupy positions as anterior as that once occupied by dp_2, as in *Trilophodon* (*Serridentinus*) *productus*, *Mastodon americanus*, and *Loxodon africanus;* the deep posterior portion of the symphyseal area, short in the immature specimen, would become shorter in maturity through the forward progression of the molars, while the anterior portion of the same area (the symphysis proper), moderately elongate and considerably depressed in immaturity, would become relatively even more depressed; and with the forward progression of the cheek-teeth there also would be a forward progression of the roots of the inferior tusks, so that the posterior opening of the tusk pulp-cavity, which lies well posterior of the posterior border of the symphysis and just beneath the anterior root of dp_2 in the immature mandible, in maturity (as seen in the Blanco *Rhynchotherium shepardi* specimen) might lie more forward and opposite the posterior border of the symphysis and anterior root of m_2 (m_2 having advanced slightly beyond the former position of dp_2).

[1] The homology of the antero-most tooth of the lower jaw cannot be in question, this tooth having no vertical successor in either *Trilophodon* or *Phiomia;* nor can that of the second and third teeth of the upper and lower jaws, as replacement premolars are not three-crested.

ADDENDA

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Page 131, first line, "*M. Stegolophodon latidens*" should read *M.* (*Stegolophodon*) *latidens*.

Page 138, first paragraph, fifth line, "*Phiomea*" should read *Phiomia*.

Page 139, first paragraph, ninth line, (*Archaedistodon*) should read (*Archidiskodon*).

Page 141, second paragraph fifth line, "apparently" should read apparent.

Page 141, third paragraph second line, omit: "Santa Fé type"; insert: (provisionally). When the complete symphyseal length of *T.* (*S.*) *pojoaquensis* is known this species may be found to actually fall within the first and extremely long symphyseal group.

Page 141, fourth paragraph, third line, after "*T.* (*S.*) *willistoni*," insert: and now must also be added the undescribed species represented by a mandible from Sansan (See Sansan note, page 177).

Page 142, Second paragraph, thirteenth line, add: Of the new material from New Mexico, "I take that specimen," etc.

Page 142, after second paragraph, insert:

Trilophodons of Sansan and Simorre (Gers) France

Since this paper went to press I have enjoyed the privilege of examining the remarkable series of mastodon remains in the collections of the Muséum d'Histoire Naturelle in Paris, and the striking mandible in the Muséum des Sciences Naturelles in Lyons. I would here acknowledge the good will and cooperation of the Directors of the two institutions, Dr. Marcellin Boule and Dr. Claude Gaillard, that have made these studies possible. It seems well to insert at this point a summary of these observations, as I find that the mature and immature remains heretofore referred in entirety to the Cuvier species, *Trilophodon angustidens*, actually include at least two widely differing species.

(1) The first, and more typical form, is exampled amongst other material from Sansan by a mandible with broken symphysis and associated skull fragment, by the mandible of the Laurillard mount, by the well preserved immature mandible with p_4, m_2 and tusks figured by Filhol (all in the Muséum d'Histoire Naturelle, Paris), by the striking mandible in the Muséum des Sciences Naturelles, Lyons, and by that from Tournan in the Muséum d'Histoire Naturelle, Paris. In all of these the symphysis is greatly extended and the diameter of the m_3 is very greatly elongated relative to m_2. The actual length of m_3, which varies in different specimens to nearly 40%, witnesses a great individual range in size (and suggests the possible presence of more than one species). The great length of the symphysis is perhaps best exhibited by the

Lyons mandible (alveolar length 420 mm., symphysis length 830 mm.) in which this and the m_3 (195 mm.) are both of record (though only proportional) length.

(2) The second, heretofore unremarked and evidently rare form is represented alone by one well preserved mandible containing m_2, m_3, and tusks of both sides and the alveolus of m_1. The alveolar distance (330 mm.) in this specimen definitely exceeds the symphyseal length (303 mm.), and the m_3 is much less elongate relative to m_2. It is worthy of remark that the anterior-posterior diameter of the particular m_3, is but slightly greater than that of the smallest m_3 of the more elongate symphyseal form, and that the range in size nearly approximates that already noted in the Santa Fé material.

The whereabouts of the first tooth (an intermediate molar, said to measure 116 mm.) mentioned by Cuvier under "Mastodonte à dents ètroites de Simorre" (I, Fig. 4) is unknown. The second and third teeth cited and figured by Cuvier (the p^4 of Plate I, Fig. 2 and the intermediate molar of Plate III, Fig. 3) are both in the collection of the Muséum d'Histoire Naturelle, Paris. The size of the last two specimens indicates that they belonged to small individuals, but whether of the extremely long or the moderately long symphyseal form, I have been unable to determine—thus the proper application of the Cuvier appelation remains in doubt. The two Sansan forms, in the present state of our knowledge, seem indivisible, on the characters of the average detached tooth, either as to cusp arrangement and form, or as to proportion and size.

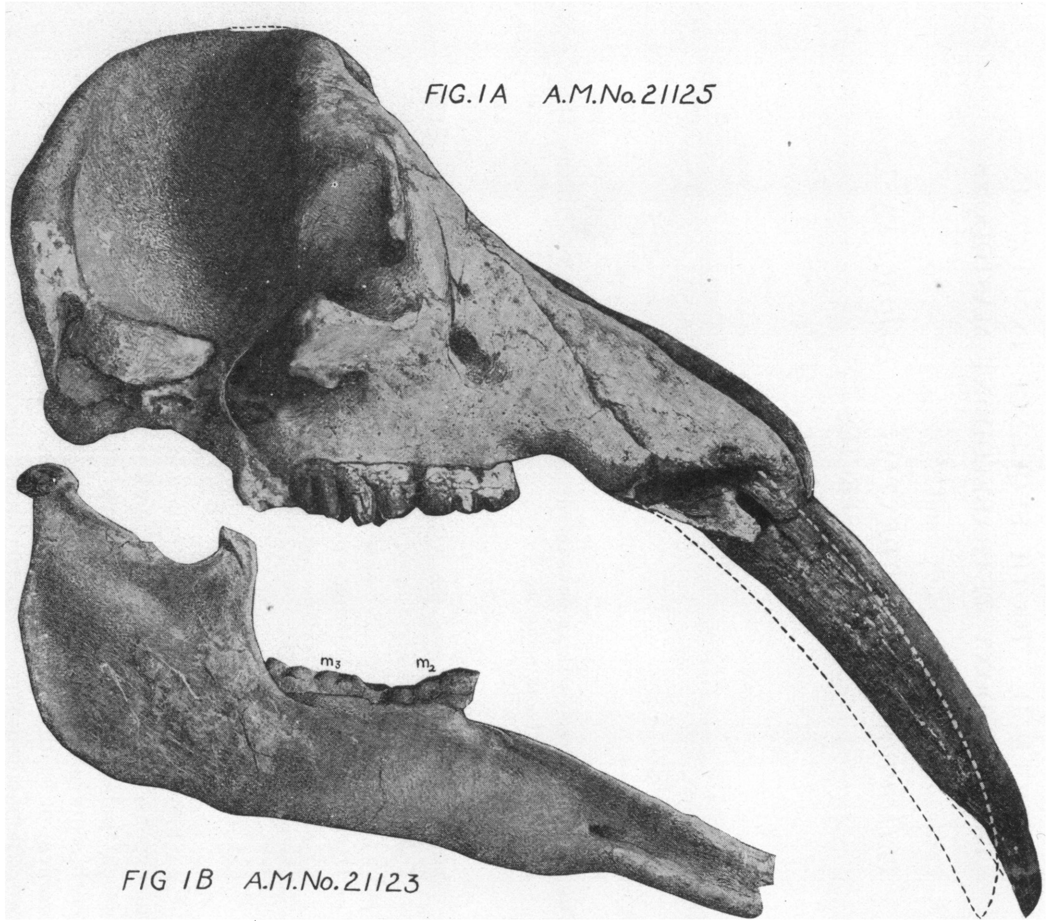
Dr. Boule's collection includes, besides the above specimens, a most instructive series of immature jaws and mandibles exhibiting various stages in the replacement of the deciduous premolars, and a considerable and most interesting variation in the absolute and relative sizes of the true premolars.

Page 147, after "*I. angustidens* of Europe" insert: as heretofore understood, (See note regarding Sansan page 177).

Page 153, second paragraph, eighth line, "figures" should read figured.

Page 155, table heading, "*E. leidii*" should read *T.* (*S.*) *leidii*.

Page 160, first paragraph, *M. augustidens* should read *M. angustidens*.



Figs. 1A–B. *Trilophodon* (*Serridentinus*) *pojoaquensis*, new species, paratypes from Santa Fé Miocene, New Mexico.
Lateral view teeth and cranium × $\frac{1}{10}$ (premaxillary areas somewhat distorted), (A) Skull, Amer. Mus. 21125 (see Fig. 27). (B) Mandible of slightly larger individual containing m_2–m_3, and bases of tusks. Symphysis somewhat crushed inferior to mental foramen. Amer. Mus.