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A NEARLY COMPLETE ARTICULATED SKELETON OF CAMARASAURUS, A SAURISCHIAN DINOSAUR FROM THE DINOSAUR NATIONAL MONUMENT, UTAH.

BY CHARLES W. GILMORE.

(PLATES XIII–XVII.)

INTRODUCTORY.

In 1899 at the time of establishing a Department of Vertebrate Paleontology, the Carnegie Museum began the systematic exploration of the Morrison formation for remains of its dinosaurian fauna, and with but few short interruptions these explorations were continuously carried on up to the close of the year 1922.

A very important period in this field of exploration was marked by the discovery in 1909 by Mr. Earl Douglass of an extensive deposit of Morrison fossils in northeastern Utah, since set aside as a part of the National Park system and designated as the Dinosaur National Monument. In the thirteen consecutive years during which this quarry was operated by the Carnegie Museum a great mass of materials, about three hundred tons in all, was collected and shipped to the museum. In these collections were many partially articulated skeletons of both large and small dinosaurs, but especially important was the recovery of a considerable series of well preserved skulls, the rarest and most sought for portions of the dinosaurian skeleton.

The great diversity of forms represented, together with their unusual perfection and excellence of preservation makes this one of the most remarkable fossil deposits that has ever been discovered in the Morrison formation. The quarry was especially rich in skeletons of the large Sauropod types, but it remained for the final year of work in excavation to disclose the most perfect skeleton of a sauropod dinosaur, which has ever been discovered. So few bones are missing from this individual that in all essentials it may be regarded as being complete. With the acquisition of this specimen it can be said, and without fear of contradiction, that the Carnegie Museum now has the largest assemblage of sauropod dinosaur skeletons of any institution in the world.

In the present paper it is proposed to give a preliminary description of the superb skeleton mentioned above in order that it may be immediately available to students of the Dinosauria. The description is preliminary in that the final preparation of the specimen was not completed at the time of my study, and undoubtedly other details of structure will be disclosed in the concluding work.

I wish here to express to Dr. Douglas Stewart, Director of the Carnegie Museum, my great appreciation for the privilege of describing this unrivaled specimen and also for having made the necessary arrangements whereby it was possible for me to undertake this agreeable task.

In the laboratory the bones of the skeleton have been skilfully worked out in relief under the direction of Mr. Arthur Coggeshall, by Messrs. Louis Coggeshall, A. Agostini, and Roy Kay.

The excellence of the drawings and restoration illustrating this paper are all due to the artistic work of Mr. Sidney Prentice, draughtsman in the Carnegie Museum.

Occurrence and Preparation of the Skeleton.

The specimen (No. 11,338, C. M. Cat. Vert. Foss.) was received at the Museum in four large blocks of sandstone. Upon bringing these blocks together into their original relationship as found in the quarry, it was seen that the skeleton was practically intact from the tip of the nose to the end of the tail, with the ribs of one side, pelvis, limbs, and feet in practically their natural positions. Some of the bones of the opposite side, however, have been shifted out of position and a few are missing.

The animal lies on its right side with the neck bent strongly upward in a sigmoid curve as shown in Plate XIII. The skull retained its normal position, *i. e.* with its longitudinal axis at an angle with the longer axis of the neck (See fig. 4). The tail likewise curves strongly upward in the anterior caudal region, sweeping forward above the line of dorsals, the distal portion cutting across the upwardly extended neck at about its middle, but at a higher level in the matrix.

The vertebral column is preserved with the vertebræ in sequence from the skull back to the tip of the tail. It would appear that the caudal series is complete, except for the loss of three centra, the ninth, tenth, and eleventh, which are represented by their articulated neural processes. In all the vertebral column consists of eighty-two vertebræ, divided as follows: cervicals, twelve; dorsals, twelve; sacrals, five; caudals, fifty-three.

On the right side there are twelve thoracic ribs in regular sequence and apparently articulated with their respective vertebræ. These remain quite regularly spaced and give a clear conception of the extent of the body cavity. The ribs of the left side are nearly all missing, only the first two remaining in position (See pl. XV). Originally other ribs of this side were present, but owing to their fragile condition they could not be preserved.

On the left side all of the cervical ribs posterior to those for the atlas are present, but those of the opposite side, if preserved, remain buried in the matrix.

The articulated fore limbs with the greater portions of both feet occupy their relative positions, the left lying above and slightly in front of the other. The preservation of the right scapula and coracoid in place beneath the ribs furnishes the first evidence in the Sauropoda as to the position and angulation of the shoulder blade in relation to the ribs and vertebral column. The proper articulated position of the scapula in the sauropod dinosaurs has long been a debated question among paleontologists and one upon which there is a considerable diversity of opinion. The evidence furnished by this articulated skeleton will be of the greatest help in arriving at a satisfactory understanding of its proper position and angulation.

The right half of the pelvic arch is complete and properly articulated with the sacrum (See Plate XIV) but the pubis is all that remains of the left side and it was shifted somewhat out of position.

The right hind limb and foot are complete. The head of the femur lies in its proper position in the acetabulum with the tibia and fibula bent backward. The left femur was found out of position below the neck, but the tibia and foot were retained in their natural place above the opposite limb, as shown in Plate XV. The articulated right hind limb furnishes indisputable evidence in favor of those who have supported the view that these animals walked in an upright quadrupedal attitude, and it should quiet for all time those who advocate a crawling, lizard-like posture for the sauropod dinosaurs.

The important bones missing from this specimen are the left ilium, left ischium, part of one sternal plate, left coracoid, all but two thoracic ribs of the left side, a few anterior chevrons and some of the smaller bones of the fore and hind feet.

A sheet of black carbonized matter found beneath and between the ribs of the right side may represent the carbonized skin and body tissues. Careful microscopical examination, however, failed to disclose a scale-pattern, such as has been found with sauropod remains in England.

The position of the skeleton is that of an animal which died a natural death, for such disarrangement as exists can be attributed to the natural shifting of the bones rather than to tearing apart by any of the contemporary carnivora.

The skeleton as shown in Plate XV has been worked out in deep relief. The few displaced bones were re-articulated, and the tail has been somewhat straightened, but otherwise the bones remain nearly as they were found. This treatment of this specimen is highly commendable since it preserves for all time the original evidence as to the proper articulation of the fore and hind limbs, as well as making clear several lesser points in the anatomy of these reptiles.

The position of most of the bones of this skeleton is shown in Plate XIV, reproduced here from a drawing made before they were disturbed.

The skeleton measured along the vertebral column has a greatest length of about seventeen feet, with a height at the hips of slightly less than five feet. That it is an immature individual is abundantly shown by its small size, the non-coalescence of the sutures and lack of rugose muscular areas on the limb and pelvic bones.

The specimen is unhesitatingly identified as belonging to the genus *Camarasaurus* Cope, as recently characterized by Osborn and Mook, and which now, according to those authorities, includes the genus *Morosaurus* of Marsh. This conclusion was reached after a careful comparison of the skeletal parts with those of *Camarasaurus* and *Morosaurus*, which have been described and figured, and although dealing with a smaller individual than any of these, such close similarities were found in the outlines, proportions, and general massiveness of the individual bones as to leave no doubt as to its generic affiliations.

In view of the very complete nature of the specimen under discussion it appears desirable to append here a synopsis of the principal osteological features of this genus. The characterization to follow has to a great extent been derived from the monographic work of *Camarasaurus supremus* by Osborn and Mook but includes such emendations and corrections as a study of this nearly perfect skeleton makes possible.

Genus CAMARASAURUS Cope.

Cope, E. D., Pal. Bull. No. 25, pp. 5–10, 1877; Osborn and Mook, Memoirs Amer. Mus. Nat. Hist., N. S., Vol. III, Pt. III, 1922, pp. 247–377, Pls. LX to LXXXV, text figs. 1 to 118.

OSTEOLOGICAL FEATURES.

Skull abbreviated, deep, with open fenestration; jaws massive, deep; lachrymal elongate, with lachrymal foramen; jugal abbreviated antero-posteriorly; quadratojugal extensive and strongly in contact with squamosal; teeth large, spoon-shaped. Dental formula: premaxillary teeth 4; maxillary teeth 12–13; dentary teeth 13. Ring of bony sclerotic plates. Hyoid arch.

Vertebral column composed of eighty-two vertebræ, divided as follows: twelve cervicals; twelve dorsals; five sacrals; fifty-three caudals. Proatlas present. Anterior cervicals with low simple spines with broad flattened tops. Cervicals beginning with the sixth have divided spines; cervicals wide, depressed; dorsal vertebræ stout; spines posterior to sixth simple, low, broad; anterior spines strongly divided; all dorsal centra depressed, of medium subequal length, and all opisthocœlus; lamination and fenestration more or less of distinct type; sacrum with short spines fused into a plate in adults; tendency toward retardation in the inclusion of sacrodorsal; anterior caudals with short spines having expanded summits; development of caudal ribs slight, disappearing posteriorly between ninth and twelfth vertebræ; anterior centra short, distal caudals never elongate.

Ribs of thorax long, slender; cervical ribs, except posterior two, long, attenuated, the longest extending the length of three succeeding vertebræ.

Pelvis: pubis short, massive; pubic foramen either open or closed; ischium characteristically of light construction with long slender shaft without distal expansion.

Pectoral arch: scapula with broadly expanded ends; coracoid subcircular; sternal plates suboval; thickened border anterior.

Carpus: usually with one ossified carpale, the radiale, always above metacarpals I and II; flattened ossicle may represent a second carpale.

Manus with five digits; metacarpals relatively slender; digit one bears the only clawed ungual; phalangial formula, I = 2, II = 1, III = 1, IV = 1, V = 1.

Femur relatively broad; fourth trochanter usually on proximal half, occasionally on middle.

Tibia stout with heavy recurved outer process; tibia and fibula slightly less than two-thirds length of femur.

Tarsus, with one ossified tarsal, the astragulus; small, rounded ossification may represent calcaneum.

Pes with five functional digits; first three bear unguals; first metatarsal short, very stout; Met. II, III, and IV comparatively slender subequal in length; Met. V shortened, with flattened expanded upper extremity; phalangial formula I=2; II=3; III=4; IV=1; V=0?

Cope proposed two species of *Camarasaurus*, *C. supremus* and *C. leptodirus*. The latter is regarded by Osborn and Mook as conspecific with *C. supremus*. Under the genus *Morosaurus*, Marsh proposed five species: *Morosaurus impar*, *M. grandis*, *M. robustus*, *M. lentus*, and *M. agilis*. He gave but few distinctive characteristics and in his *Dinosaurs of North America* made no attempt to distinguish them, except to illustrate a few bones of the different species.

Morosaurus impar is the genotype, but as Williston[1] has pointed out, it is clearly a synonym of *M. grandis*. Riggs[2] correctly interprets the synonomy of the two species as follows: "while the specimen upon which the former species was based must remain the generic type, that of the latter being much more complete and better known will naturally be referred to in comparisons." *M. robustus* was established upon a single ilium of large proportions, and it may eventually fall within the species *C. supremus*. *M. lentus* is based on considerable portions of the skeleton of an immature individual, and according to Riggs[3], who has examined the type materials, "is not to be distinguished by the sutural articulation between the centrum and the neural arch of the vertebræ as Marsh's figures would suggest, but by the massiveness of all parts of the skeleton and the depression of the vertebral pedicles so that the neural arch rests directly upon the centrum."

M. agilis, as first pointed out by Gilmore[4] and further confirmed by direct comparison of the type materials with the present specimen, does not belong in the genus *Camarasaurus* and may be dismissed from further consideration in that connection.

From the above brief review of the seven species originally proposed only four may be considered valid at this time. These are: *C. supremus* Cope, *C. impar* (Marsh), *C. robustus* (Marsh), and *C. lentus* (Marsh).

A revision of these species is far beyond the scope of the present paper, and is a piece of work provided for in the monographic study of the Sauropodous dinosaurs which Prof. Henry F. Osborn and his associates now have under way. Until such time as the *Morosaurus* type materials are restudied and the species adequately characterized, the reference of new materials to any of them is attended with much uncertainty. The assignment of the present specimen to any of these species would be more or less doubtful, although its small size, stoutness

[1] Kansas Univ. Quart. vol. VII, p. 173.

[2] Field Columbian Museum, Pub. 63, vol. I, 1901, p. 275.

[3] *Loc. cit.* p. 275.

[4] Proc. U. S. National Museum, vol. 32, 1907, pl. 163.

of the skeletal parts, together with depressed pedicles of the dorsal vertebræ resting directly upon the centra, and pubis with an open pubic foramen, constitute an assemblage of characters in common with the type of *Camarasaurus lentus* that apparently indicate the affinities of the present specimen to lie in that species.

OSTEOLOGICAL DESCRIPTION.

The Skull.

The skull of specimen No. 11,338, C. M. is the most perfect cranium of *Camarasaurus* (*Morosaurus*) that has yet been discovered. It has been slightly compressed, but the distortion is so little as to be almost negligible, and it gives a very clear conception of its original shape and proportions. Since it pertains to an individual not yet mature nearly all of the sutures are clearly indicated. The skull has not been completely extracted from the sandstone matrix but with the exception of the palate the structure from all other aspects is shown.

Hitherto our knowledge of the Camarasaurian skull has been limited to the posterior part of the cranium of "*Morosaurus*" *agilis* (Marsh) described by Marsh[5] and by Gilmore[6]; the more or less complete skull of *Camarasaurus grandis* (Marsh) briefly described by Osborn[7]; the posterior portion of a skull of *Morosaurus grandis* figured by Marsh[8] and the fragmentary skull of *Camarasaurus supremus* Cope described by Osborn and Mook.[9] This new skull, therefore, greatly extends our knowledge, especially in bringing about a better and more accurate conception of its detailed structure.

The skull described by Osborn, although somewhat restored, closely approximates the general form and proportions of the cranium now in hand, but it is now possible to correct certain errors of detail detected in the restored skull, although on the whole it is remarkably accurate, considering the limited knowledge of the cranium of *Camarasaurus* at the time of its reconstruction. Since the skull of *Camarasaurus* was very briefly described by Osborn, a detailed description of the Carnegie Museum specimen appears highly desirable.

The skull of *Camarasaurus* can be distinguished at once from that of *Diplodocus* by its abbreviated face with highly arched forehead or anteorbital region, and by the presence of large spoon-shaped cropping teeth. From the posterior aspect, however, the differences are not so clearly defined, as will be pointed out farther on.

[5] Amer. Jour. Sci., vol. 37, 1889, p. 334.

[6] Proc. U. S. National Museum, vol. 32, 1907, pp. 151–157.

[7] Science, vol. 22, No. 560, 1905, pp. 374, 375; Nature, vol. 73, 1906, p. 283, fig. 2.

[8] 16th Ann. Rept. U. S. Geol. Survey, pt. I, 1896, pl. XXX, fig. 2.

[9] Memoir Amer. Mus. Nat. Hist. N. S., vol. III, pt. III, 1921, pp. 284–290.

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Viewed from the side the general structure of the skull is open and of slender construction as in the carnivorous dinosaurs. The posterior portion is deep dorso-ventrally and moderately wide transversely. The facial portion, as mentioned previously is shortened, slightly tapering toward the front when viewed from above with an obtusely rounded muzzle, as contrasted with the almost squarely truncated beak of *Diplodocus*.

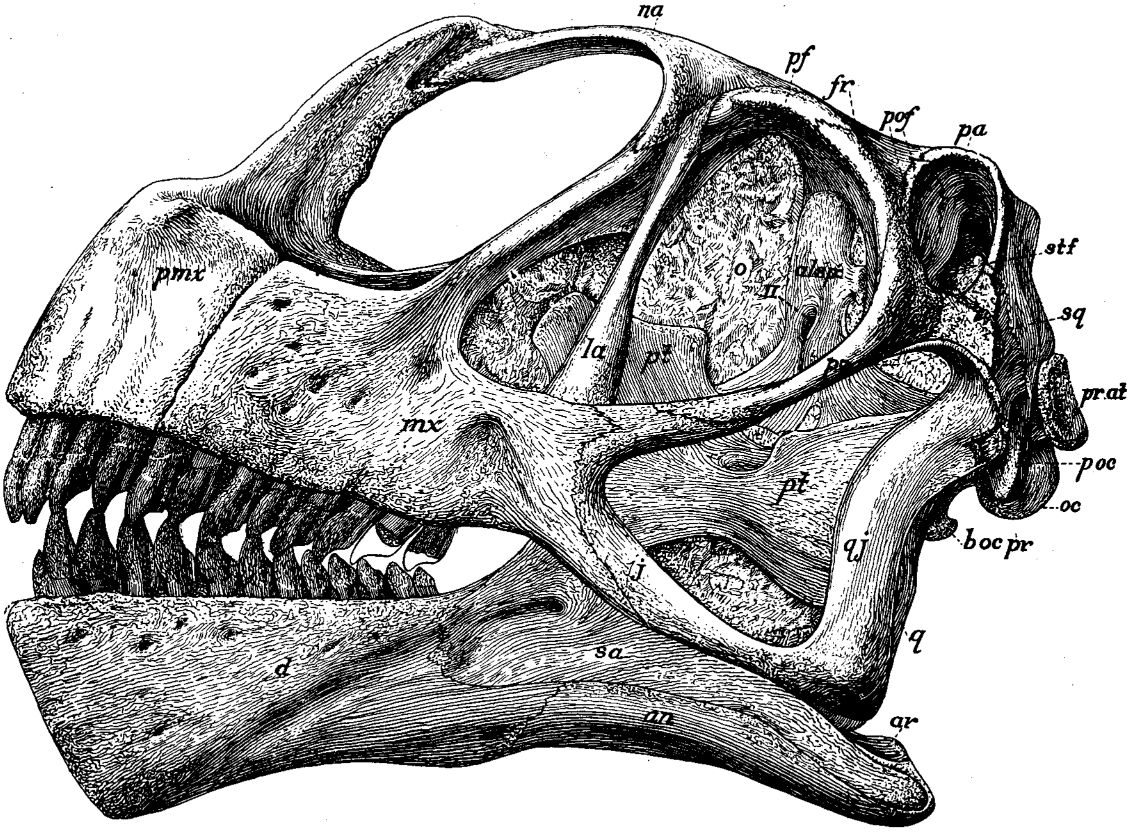


FIG. 1. Skull and lower jaws of *Camarasaurus lentus* (Marsh) No. 11,338, C. M. Viewed from the left side. Three-sevenths natural size. *alsp*, alisphenoid; *an*, angular; *ar*, articular; *bocpr*, basioccipital process; *d*, dentary; *fr*, frontal; *j*, jugal; *la*, lachrymal; *mx*, maxillary; *na*, nasal; *o*, orbit; *oc*, occipital condyle; *pa*, parietal; *pf*, prefrontal; *pmx*, premaxillary; *po*, postorbital; *poc*, paroccipital process; *pof*, postfrontal; *pr.at*, proatlas; *pt*, pterygoid; *q*, quadrate; *qj*, quadratojugal; *sa*, surangular; *sq*, squamosal; *stf*, supratemporal fossa; II, optic foramen.

The plane of the occiput forms an obtuse angle with the fronto-parietal part of the skull. The occipital condyle, as Holland[10] has so clearly pointed out in *Diplodocus*, is directed downward at nearly a right angle to the longer axis of the skull. Viewed from the back the skull is sub-rectangular in outline with the greatest diameter perpendicular. The sutural contacts of the occipital segment are rather obscure if not in most cases completely obliterated. With the aid of the

[10] Memoirs of Carnegie Museum, vol. II, No. 6, 1906, pp. 228–230.

type cranium of *Morosaurus agilis* Marsh in which most of the sutures are clearly defined it has been possible by direct comparison to work out the line of sutural contact between the parietal and the underlying supraoccipital and exoccipital bones with a considerable degree of assurance of their correctness as shown in figure 3. The other elements of the occiput could not be delimited.

The basioccipital is composed of the subtrilobate condyle and the long, heavy, descending basioccipital processes. The exoccipitals contribute extensively to the formation of the occipital condyle and apparently exclude the basioccipital from participation in the boundary of the foramen magnum as is also clearly shown in *M. agilis*, *Atlantosaurus montanus*,[11] and also in *Antrodemus fragilis* and *Ceratosaurus nasicornis*.[12] Although the evidence is hardly extensive enough as yet upon which to base a positive assertion, it would seem that in the Saurischia the basioccipital is nearly always excluded from the foramen magnum whereas in the Ornithischia it always participates in the formation of the lower median boundary. This feature of the Ornithischia is well shown in *Camptosaurus*,[13] *Stegosaurus*,[14] and in the Hadrosauridae.

The supraoccipital cannot be differentiated, and the description to follow of the exoccipitals undoubtedly includes this bone.

The exoccipitals are not as broad and strongly developed as in *Diplodocus*, and their outer extremities or paroccipital processes are more strongly deflected ventrally than in that genus. The combined elements from the posterior aspect are subtriangular in outline. The upper part of the triangular apex probably represents the coalesced supraoccipital bone. The exoccipitals probably meet broadly on the median line and entirely exclude the supraoccipital from the foramen magnum, as in *M. agilis* and as Holland has found the relations of these bones to be in the skull of *Diplodocus carnegiei*.[15] Laterally these median elements articulate with the parietal and squamosals, the articulation with the latter being entirely with the paroccipital process, which extends outward, backward, and downward. On the median posterior surface of the supraoccipital area there is a pronounced vertical ridge developed as in *Diplodocus* and corresponding in position also to the more robust projection found in the skull of *Antrodemus fragilis*. The parietal is very short antero-posteriorly and enters very little into the composition of the cranial roof (See fig. 2). At the center it has an antero-posterior diameter

[11] 16th Ann. Rept. U. S. Geol. Surv. Pt. I, 1896, pl. XV, figs. 1 and 2.

[12] Bull. No. 110, U. S. Nat. Mus., 1920, p. 79.

[13] Proc. U. S. Nat. Mus., vol. 36, 1909, fig. 4.

[14] Bull. No. 89, U. S. Nat. Mus., 1914, fig. 4.

[15] *Op. cit.* fig. 4.

of only 20 mm. Anteriorly the coalesced parietals join the frontals by a nearly straight transverse suture that extends from the median anterior boundary of the supratemporal fossa to join the postfrontal at a similar point on the opposite side. Viewed from above (See fig. 2) the parietal presents a narrow flattened median

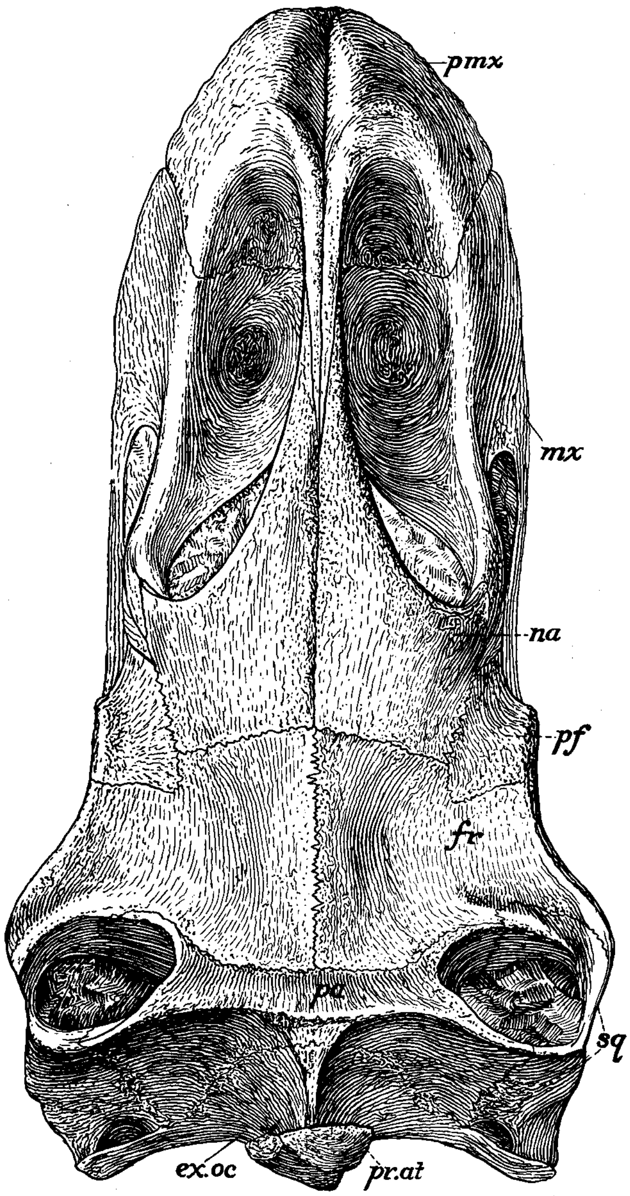


FIG. 2. Skull of *Camarasaurus lentus* (Marsh) No. 11,338 C. M. Superior view. One-half natural size. *exoc*, exoccipital; *fr*, frontal; *mx*, maxillary; *na*, nasal; *pa*, parietal; *pf*, prefrontal; *pmx*, premaxillary; *pr.at*, proatlas; *sq*, squamosal.

surface and two vertical processes that extend in front and back of the supratemporal fossa respectively. The posterior process is directed outward and slightly backward in relation to the central axis of the bone much as in the theropods.

They rise slightly above the level of the median superior surface of the parietal forming a broad shallow concavity when viewed from the rear (See fig. 3). The parietals form all of the inner and most of the posterior boundaries of the supratemporal fossa. The posterior lateral parietal process overlaps the squamosal at its outer extremity. In posterior aspect (See fig. 3) the lateral processes of the parietal are broad and wing-like at their outer extremities but rapidly narrow toward the median line. The anterior lateral process meets the postfrontal by a vertical process within the fossa and entirely excludes the frontal from participation in the supratemporal boundaries.

The *frontals* are united on the median line by a distinct interdigitating suture. They are broader than long and superiorly present shallow concave surfaces on either side of the median line which is slightly elevated. Laterally they extend outward to form the upper boundary of the orbit. This portion is interposed between the pre- and postfrontals. Over the orbital cavities the bone is thick and heavy, measuring eight millimeters in thickness. The exterior margins antero-posteriorly are shallowly concave, with a vertical rounded border which is somewhat roughened. Between the orbits the frontals have a greatest transverse diameter of 116 mm. The orbital contribution measures 31 mm. antero-posteriorly.

The frontals, as mentioned above, do not participate in the boundaries of the supratemporal fossa. Posterior to the orbital border they have a wide sutural contact with the postfrontal. The fronto-nasal suture is rather obscure but its tentatively determined course is shown in fig. 2, but the evidence is very inconclusive. As thus determined the frontals would have a greatest length on the median line of 65 millimeters.

The *nasals* are relatively short, broad posteriorly, with attenuated anterior extensions, which go forward above the anterior nares to lap the premaxillaries. Laterally, at the posterior end the nasals send a short pointed triangular process abruptly downward to meet the long slender ascending process of the maxillary, and thus completes the posterior boundary of the narial orifice (See fig. 1). Posteriorly they unite medially with the frontals, and laterally with the prefrontals and lachrymals. The upper surfaces of these bones are broadly rounded from side to side. The pointed anterior ends appear to be separated by the slender processes of the premaxillaries. The nasals have a greatest length in this specimen of about 112 mm., a greatest transverse diameter of about 96 mm. Across the center of the nares the width diminishes to 19 mm.

The postfrontal and postorbital are firmly coalesced and there no longer remains any indication of their sutural junction. This bone undoubtedly represents, as in the Theropoda, a complex of two elements. On the median internal side, best seen on the left side of the present specimen (fig. 1 *alsp.*) at the back of the orbit, the outer end of the alisphenoid is seen to articulate. In those dinosaurian skulls in which the postorbital and postfrontal bones are found as distinct elements, this end of the alisphenoid is always received in a cupped depression on the inner side of the postorbital. On this evidence it would appear, therefore, that the line of sutural articulation of these two bones must be above this contact with the alisphenoid. This complex has the usual triradiate shape, a short heavy process which extends inward and articulates with the parietal and frontal and forms the outer two-thirds of the anterior wall of the supratemporal fossa; a smaller and more slender posteriorly directed process that meets the squamosal to form the short upper temporal bar; the third, much the longest one of the three, extends downward and forward and joins the posterior process of the jugal by a long oblique squamous suture, thus forming the postorbital bar, which separates the orbital from the infratemporal opening. This bar is trihedral in cross-section, and it has the strong diagonal direction found in *Diplodocus* rather than the more vertical position found in the Ornithischia and the carnivorous Dinosauria.

The *prefrontal* is a small triangular element that forms the upper anterior boundary of the orbit. Its widened posterior end and internal border articulates with the frontal and nasal. Proceeding forward it rapidly narrows to a sharp extremity that turns strongly downward to lap along the posterior upper side of the lachrymal (See fig. 1).

The *lachrymal* in *Camarasaurus* is especially elongated and slender, and quite unlike any other dinosaurian lachrymal with which I am acquainted. In the articulated skull it stands nearly vertical in relation to its longer axis. The distal end is comparatively thin transversely but widened antero-posteriorly. It articulates with the jugal and maxillary above their junction, the contact being more extensive with the latter than with the former bone (See Plate XVI). Proceeding superiorly in lateral view the lachrymal contracts antero-posteriorly into a narrow bar (See fig. 1), but from the middle upward, from a posterior view it widens transversely, the upper extremity being intercalated between the prefrontal, nasal, and the ascending maxillary process. On the posterior side of the upper third the bone is perforated by a vertically elongated lachrymal foramen. This bone forms the bar separating the large anteorbital fenestra from the orbital cavity.

The *jugal* is an exceedingly abbreviated, triradiate bone that participates but slightly in the lower boundary of the orbit. The anterior end has a wide dorso-ventral contact with the maxillary being overlapped by that bone. A slender tapering process extends backward and upward at an angle of 45° and joins the postorbital by a long diagonal squamous suture. This superior process is unusually short. The third or inferior process is directed slightly downward and strongly backward to join the quadratojugal beneath the infratemporal fossa. The extent

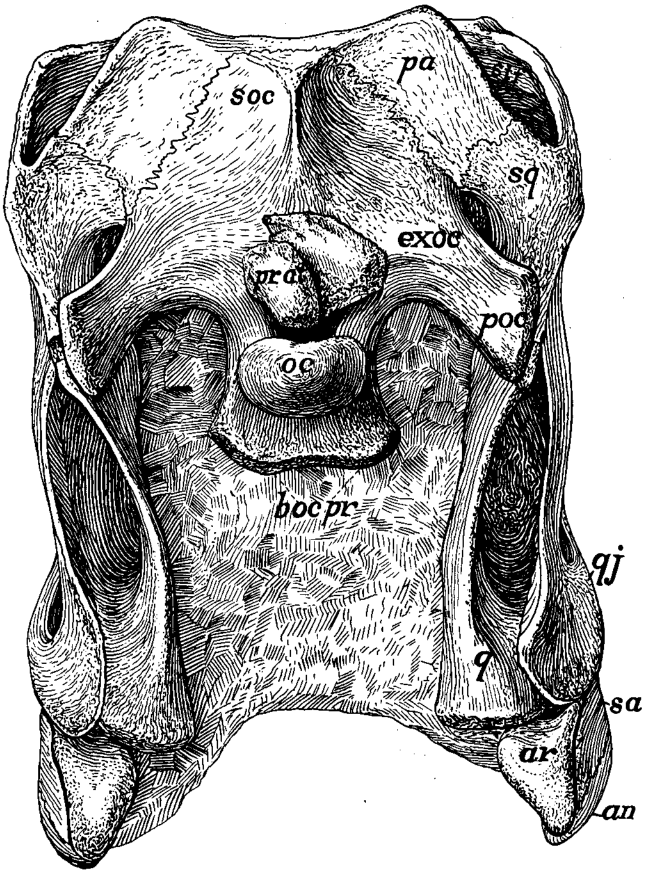


Fig. 3. Skull and lower jaws of *Camarasaurus lentus* (Marsh) No. 11,338, C. M. Posterior view. One-half natural size. *an*, angular; *ar*, articular; *bocpr*, basioccipital processes; *exoc*, exoccipital; *oc*, occipital condyle; *pa*, parietal; *poc*, paroccipital process; *pr.at*, proatlas; *q*, quadrate; *qj*, quadratojugal; *sa*, surangular; *soc*, supraoccipital; *sq*, squamosal; *stf*, supratemporal fossa.

or manner of articulation of these two bones cannot be determined in this specimen, but the bar is long and very slender as shown in figure 1.

The *squamosal* fits very snugly over the head of the quadrate and it nearly excludes the quadrate from contact with the paroccipital process, as in *Antrodemus*. The relationship of these bones is slightly obscure. The squamosal is a small, irregularly shaped element that is strongly interposed between the other elements of the upper posterior angle of the skull. Its inner extension meets the parietal and posteriorly it appears to meet the paroccipital process. It seems to contribute to the boundary of the supratemporal fossa, though the exact outlines of the bone are not entirely clear in this specimen.

The *quadrate* bones are perfectly preserved. Neither one has been fully uncovered, but from a study of both a very clear conception of the entire structure has been obtained. Although it has an appearance of stoutness, the quadrate is relatively light in construction due to deep excavations on both front and back surfaces. The distal end which articulates with the lower jaw is massive and stout; it is concave on its anterior surface and slightly convex on the lower posterior face; the end is obliquely truncated, the longer side being internal. Distally it presents two articular faces, the inner being at right angles to the long diameter of the shaft, the outer being oblique in both anterior and external directions. The quadrate has a greatest length of 120 mm. as contrasted with the quadrate of *Camarasaurus supremus* described by Osborn and Mook[16] with a greatest extent of 270 mm. Viewed from the side the upper part of the quadrate curves strongly backward. The extent of the quadratojugal articulation cannot be certainly determined, although it is tentatively regarded as having the extent shown in figure 1. On the inner anterior side a vertically wide but thin plate extends forward at the back of the infratemporal fossa to articulate with the pterygoid as shown in figure 1. Its inferior border is convex. The internal side has not been uncovered, but on the basis of the quadrate described by Osborn and Mook it probably turns up on the lower internal side forming a pocket-like excavation for the lodgment of a process from the pterygoid. A somewhat similar condition prevails in the skull of *Antrodemus*. In the front between the outer anterior border and the thin, inner, anteriorly directed process for the pterygoid, the quadrate is quite deeply excavated. On the opposite or posterior face there is also a deep longitudinal pocket, so that the bone between these two excavations is very thin.

The *quadratojugal* cannot be entirely delimited in this specimen though it seems to be extensive dorso-ventrally, resembling the Theropods in this respect, especially such forms as *Antrodemus* and *Tyrannosaurus*. From a lateral view it appears to articulate with the squamosal near the top of the quadrate, as in the carnivorous dinosaurs and thus to entirely exclude the top of the quadrate. From analogy it would also seem that such was the case. It unites by a squamous suture with the external side of the quadrate, a thin posterior portion a little

[16] Memoirs Amer. Mus. Nat. Hist., n. s. vol. III, pt. III, 1921, p. 288.

above the distal end remaining free and forming the outer wall of the deep longitudinal pocket or recess in the back of the quadrate, when viewed from the back (See fig. 3). The distal end extends below the level of the outer articular end of the quadrate forming an obtuse notch between the two bones. A forwardly directed process from the lower end meets the jugal, the two forming the long slender bar, which bounds the lower border of the infratemporal fossa.

The *premaxillary* is a heavy rectangular bone, with a long, thin superior process which extends upward and backward from the anterior superior border and with its fellow of the opposite side divides the external narial orifice into right

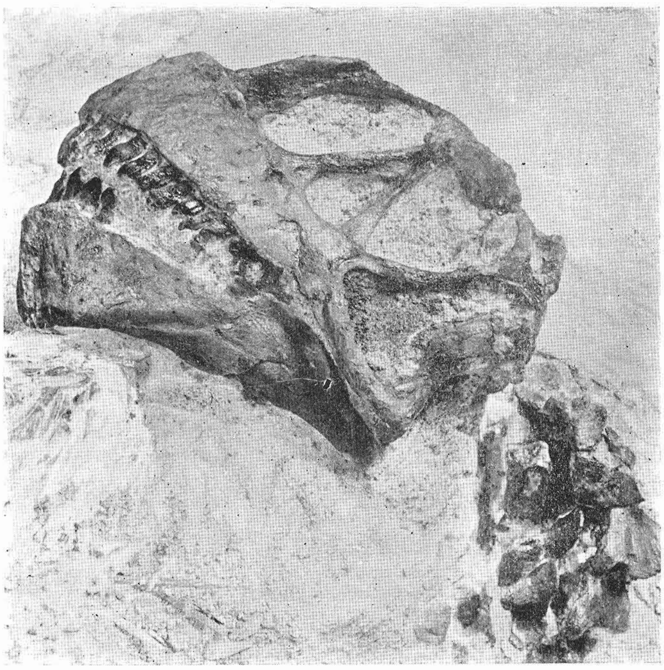


FIG. 4. Skull and neck of *Camarasaurus lentus* (Marsh) (No. 11,338, C. M. Cat. Vert. Foss.) Viewed from left side. One-fifth natural size. Shows relations of skull and anterior cervicals as originally found in the matrix.

and left nares. This process unites above the center of the nares with the slender anterior process from the nasals by a long lapping sutural contact. Though thin transversely, this process widens rapidly antero-posteriorly toward its point of origin. On the anterior margin at the base of this process, there is a decided offset between it and the heavier dentigerous portion which gives the muzzle a decidedly dished profile, as contrasted with the regularly convex nose of the carnivorous dinosaurs. On the inner side approaching the anterior end the contact with its fellow of the opposite side is evidently a flattened surface, that is oblique to the longer axis of the bone. Posteriorly it unites with the anterior end of the maxillary by a nearly straight vertical suture. In *Camarasaurus* the premaxillary carries four teeth, the longest and largest of the entire upper dental series. The articulated premaxillæ show a decided depression following the median suture below the base of the superior process (See fig. 2). This depression fades out more ventrally and the muzzle is evenly rounded from side to side above the alveolar border. The heavy block-like portion of the premaxillary has a greatest diameter, measured around the curve antero-posteriorly, of 75 mm.; its greatest depth from dental to nasal border is 80 mm. Attention should be called to the striking similarity of this bone to the premaxillary in *Antrodemus*.

The *maxillary* is heavy and especially broad vertically in its anterior portion, becoming narrower posteriorly. The superior bar of the maxillary is stout and especially produced upward and slightly backward from the main mass of the bone. It gradually widens antero-posteriorly at the upper extremity preceding its junction with the attenuated lachrymal. Toward the distal part of this process a thin transverse flange is developed which is directed inward and forward and joins its fellow of the opposite side on the median line. From their junction they extend anteriorly as a thin median septum to meet a posteriorly directed pair from the premaxillæ. Between this septum and the lower external face is a shelf-like offset that forms the floor of the narial orifice. The inferior mass of the maxillary presents a broad smooth lateral surface that is pitted here and there with foramina. The inferior edge of the maxillary is deflected slightly outward, forming a border for the protection of the immature teeth. The posterior end unites wholly with the jugal by a nearly vertical concave suture. Measured along the outer side of the alveolar border the maxillary has a greatest length of 142 mm. The left maxillary has eight fully erupted spoon-shaped teeth; the right has nine.

The *alisphenoid* is visible on the left side of the skull which has been divested of its matrix to the median line, and thus exposes this side of the brain case. Its full outline cannot be traced, but as in all other dinosaurs its outwardly directed branch, meets the inner side of the postorbital probably in a cupped depression on the inner side of that bone. Above it is certainly in contact with the frontal and possibly also with the parietal. Anteriorly it overlaps what appears to be the orbitosphenoid. It is perforated by a large foramen thought to be the optic (See fig. 1, II). I am unable to differentiate the other elements of the brain case in the present partially prepared condition of the skull.

The posterior end of the left pterygoid is exposed showing it to send upward a high, broad, nearly vertical plate forward of its junction with the quadrate. This portion of the pterygoid is plainly visible within the orbit (See fig. 1) and its anterior end is to be seen projecting forward of the lachrymal within the antorbital fenestra. A short, stout, transversely directed process joining the pterygoid and maxillary on the inside immediately below the lachrymal probably represents the ectopterygoid bone. The sutural divisions, however, cannot certainly be determined. The presphenoid is partly exposed.

The Lower Jaw.

The *dentary* in *Camarasaurus* is especially massive and affords a most striking contrast to the slenderer dentary of *Diplodocus*. It is deepest vertically at the symphysis, which measures 83 mm. from the alveolar to the ventral border. This vertical diameter gradually grows less posteriorly. The front of the chin is broadly rounded from side to side, the two dentaries uniting by a strong median symphysis. The chin is slightly receding. The external surface, especially the anterior half, is dotted with pits, probably vascular foramina as in the premaxillary and maxillary above. Antero-posteriorly the dentary has a greatest length taken at the center of about 164 mm. As in the maxillary the superior edge sets out from the teeth. The posterior end overlaps the angular below and the surangular above. Viewed laterally the dentary is deeply excavated at the posterior end at its junction with the surangular (See fig. 1). Below the dentary-surangular suture, it sends back a wide, triangular process, which extends backward underneath the surangular and overlaps the angular. Posterior to the last tooth the superior border meets the coronoid. In this specimen the dentary carries thirteen teeth, evidently the complete series. These occupy a longitudinal space of 128 mm.

The *angular* forms the lower portion of the posterior half of the ramus. It underlies the more robust surangular and the articular. Anteriorly it is overlapped by the dentary.

The *surangular* with the small coronoid forms the whole of the upper external face of the ramus posterior to the dentary. Narrow at its posterior extremity it gradually widens anteriorly to the coronoid where it again becomes narrower as it approaches the dentary. A small external mandibular foramen perforates the bone as in *Camptosaurus*.

The *articular* is a small block-like bone, longer than wide, with a shallowly fossate upper surface that constitutes the principal articulation for the quadrate. Viewed posteriorly (See *ar.* fig. 3) it is subtriangular in outline, wide above, and obtusely pointed below. Laterally it is lapped by the surangular and angular. The articular projects posteriorly slightly beyond the posterior termination of these elements (See fig. 1) and thus forms the profile of this end of the ramus. Its anterior and internal relationships are largely hidden by the enveloping matrix.

On the inner anterior side of the articular a thin bone, protruding posteriorly from the matrix, may represent the prearticular.

The *coronoid* forms a low convex coronoid process, which in the articulated skull passes upward behind the maxillary and when the jaws are closed is not visible from a lateral view.

The other elements of the lower jaw are hidden by the matrix, which has not been removed from between the jaws.

External Openings in the Skull.

Viewed from the side the openings in the skull of *Camarasaurus* beginning posteriorly are the lateral temporal fenestra, the orbital opening, the anteorbital fenestra, and the anterior nares. Viewed superiorly the paired supratemporal fossæ are the only openings. I can find no trace of a pineal foramen, although Osborn[17] observed it in skulls of this genus belonging to the American Museum of Natural History.

The *lateral temporal fenestra* is an obliquely elongated opening that is stirrup-shaped in outline, narrow above and wide below. It is bounded above by the posttemporal bar formed by the curved anterior process of the quadrato-jugal; anteriorly by the postorbital bar, formed about equally by the processes of the postorbital and jugal bones; ventrally by the quadratojugal and jugal. Its greatest oblique diameter is 116 mm.; its greatest antero-posterior diameter is 78 mm.

The *orbital cavity* like the temporal fenestra is elongated obliquely, but widest at the top and narrowed to an acute angle at the bottom. The restored skull figured by Osborn[18] is in error so far as the correct outline of the orbit is concerned, being too large and with the lower portion especially wide and out of proper proportion. The doubtful correctness of this region was fully recognized by Osborn. Dorsally the upper boundary is formed by the postfrontal, frontal, and prefrontal; anteriorly by the prefrontal, but principally by the lachrymal; ventrally by the jugal, and posteriorly by the descending and ascending branches of the postorbital and jugal respectively. The orbit has a greatest supero-inferior diameter of 112 mm.; a greatest transverse diameter of 80 mm.

The *anteorbital fenestra* is strikingly larger than in *Diplodocus* resembling more nearly the conditions found in the carnivorous dinosaurs. It is acutely pear-shaped in outline. Its upper, anterior, and inferior boundaries are formed by the maxillary and its superior process; the posterior by the lachrymal. The greatest diameter supero-inferiorly is 60 mm.; greatest transverse diameter is about 35 mm.

[17] Nature, vol. 73, 1906, p. 284.

[18] *Loc. cit.* fig. 2.

The *external nares* are very large and face more directly forward than upward. There is no roofing over of the nares by the processes of the premaxillaries as found in many reptilian skulls. This opening is bounded above by the slender processes of the nasal and premaxillary bones; anteriorly by the premaxillary; below by the premaxillary and maxillary, and posteriorly by the maxillary process and nasals. It has a greatest oblique diameter of about 125 mm.; an antero-posterior diameter of about 65 mm.

The *supratemporal fossa* is suboval in outline with its greatest diameter at right angles to the longer axis of the skull. The external wall is much lower than its other boundaries so that the fossa looks strongly outward as well as upward. The inner and posterior wall is formed almost exclusively by the parietal, the squamosal entering only slightly into its outer posterior and external boundaries. The inner third of the anterior wall is formed by the parietal, the outer half by the postfrontal postorbital complex. Beneath these bones the alisphenoid may also contribute to the inferior boundary. The greatest oblique transverse diameter of this fossa is 55 mm.; the greatest antero-posterior diameter is 28 mm.

TEETH.

The dental formula of *Camarasaurus*, as clearly shown by this specimen, is as follows:

Upper jaw: premaxillary 4; maxillary 8–9; total 12–13.

Lower jaw: dentary 13.

Osborn and Mook[19] found only eight teeth in the maxillary of a specimen from the "Bone Cabin" quarry in Wyoming. It therefore appears that the number of teeth in the upper jaw may be found to vary slightly among different individuals, as is known to be the case in the carnivorous dinosaurs. In the present specimen there are eight maxillary teeth on the left side and nine on the right.

Only the external view of the dental series is to be observed in this specimen at the present time. Nearly all of the teeth are fully erupted and functional in this individual. The teeth are homodont, small posteriorly, but becoming steadily larger toward the front in both upper and lower series. On the whole the teeth of the upper jaw seem to be slightly more robust than those of the dentary. Otherwise from an external view I fail to detect any peculiarities for distinguishing upper from lower. The unworn teeth have obtuse points that have the appearance of raking slightly backward, brought about by a concavely cut out condition on the posterior-superior border or posterior-inferior border of the crown, whether it be upper or lower tooth. This condition prevails on the lateral maxillary teeth,

[19] *Op. cit.* p. 290.

as in all of those of the dentary. The premaxillary teeth have the two borders of the crown evenly convex coming to a blunt median point. Externally the crowns of the teeth are broadly convex. These surfaces are composed of a finely pitted type of enamel. On the external surface a vertical groove sets off a narrow posterior strip from the main mass of the tooth. It is presumed that the roots are cylindrical and the interior face of the crowns are spoon-shaped, as described by Osborn and Mook in *Camarasaurus supremus* and by Marsh in *Apatosaurus*. The lower teeth bite within the upper in the articulated jaws. The most anterior premaxillary tooth has a greatest length measured from the alveolar border of 31 mm.; the most posterior maxillary tooth of the right side projects only 10 mm. All of the lateral teeth rake decidedly forward, in both upper and lower series and all curve slightly inward.

MEASUREMENTS OF SKULL AND LOWER JAWS.

Greatest length of skull over all	330 mm.
Greatest width across tops of quadrates	147 mm.
Greatest width above center of orbits	115 mm.
Greatest width above center of nares	15 mm.
Distance from posterior border of orbit to posterior extremity of squamosal, about	68 mm.
Distance from anterior border of orbit to anterior extremity of premaxillæ, about	190 mm.
Distance from extremity of premaxillæ to distal extremity of quadrate	286 mm.
Distance from distal end of quadrate to top of skull, about	175 mm.
Height of skull through center of orbit	165 mm.
Height of skull with lower jaw, taken at posterior end	205 mm.
Height of skull with lower jaw, taken at center of orbit	215 mm.
Height of skull with lower jaw, taken at front of superior process of premaxillary, about	200 mm.

LOWER JAWS.

Greatest length of ramus over all	280 mm.
Greatest depth of ramus below quadrate	25 mm.
Greatest depth of ramus through coronoid process	67 mm.
Greatest depth of ramus at anterior end	80 mm.
Greatest breadth of rami, articulated with quadrates, about	125 mm.

SCLEROTIC RING.

In the matrix filling the right orbit, the nearly complete but slightly disarranged sclerotic ring was preserved as shown in plate XVI. the second occurrence in the Sauropodous dinosaurs, and the first time found in the genus *Camarasaurus*. This ring is present in a skull of *Diplodocus* No. 11,255 in the Carnegie Museum, and since they are now known in the Ceratopsidæ, Hadrosauridæ, and the Sauropoda there is reason for believing that sooner or later they will be found in all dinosaurian reptiles.

In the present specimen the preservation is such that neither the number of scelrotic plates nor the method of their arrangement can be determined.

Hyoid Arch.

That there is a well developed hyoid apparatus in the Sauropod dinosauria is shown by the preservation in the matrix beneath the lower jaws of three rod-like bones, which undoubtedly represent elements of the hyoid arch. The longest of these measures 165 millimeters in length. Two of them are paired and probably represent the thyrohyal bones.

Vertebral Column.

The vertebral column as determined from this continuous articulated series has the following formula: cervicals 12; dorsals 12; sacrals 5; caudals 53. The cervical formula does not include the proatlas, which is apparently present and attached to the skull as shown in figure 3.

In giving the formula as above the cervical, dorsal, and sacral series may now be considered as absolutely determined, since they are based on a continuous articulated series beginning with the atlas and ending with the forty-seventh caudal. At this point there is a slight disarrangement but since these disturbed caudals regularly diminish in length posteriorly it appears to indicate that none are missing. A total number of 53 is actually present, which agrees with the estimate of Osborn and Mook of the complete series in *Camarasaurus supremus.* There is reason for believing that the total number of caudal vertebrae will not be constant, but may vary with the individual, even within a species.

The total number of presacrals disagrees with the tentative determination made by Osborn and Mook for *C. supremus*, and their interpretation of the division of these between neck and thoracic regions does not coincide with the evidence furnished by the present specimen. Their estimate of the formula is: cervicals 13; dorsals 10–11; sacrals 5–4; caudals 53. In consideration of the fact that they were dealing with disarticulated series, the accuracy of the results obtained is remarkable. The determination of the number of dorsals is made on the evidence of there being 12 undoubted thoracic ribs preserved in regular sequence on the lower or right side of the skeleton, as shown in Plate XIV.

The vertebral column in *Camarasaurus* as compared with other known Sauropoda shows a reduced number of cervicals and an increased number of dorsals, except for *Haplocanthosaurus* which, if correctly determined by Hatcher, has a greater number of dorsals than any known member of this group. These facts are graphically set forth in the table below:

	Cervicals	Dorsals	Sacrals	Caudals
Camarasaurus lentus (Marsh)	12	12	5	53
Apatosaurus louisæ Holland	15	10	5	82
Diplodocus carnegiei Hatcher	15	10	5	73
Haplocanthosaurus priscus Hatcher	(Unknown)	14	5	—

The vertebral series in *Camarasaurus* is characterized by the compactness and stoutness of the individual vertebræ; the dorsals, especially the posterior members, by their low and wide spines, and the opisthocoelous character of the centra of the presacral series; the caudals by their short spines and weakly developed transverse processes, and the absence of a long attenuated distal extension of the tail.

The vertebræ agree with other Sauropods in having pleurocentral cavities in the presacrals, and divided spines in the postero cervical and antero dorsal regions. As pointed out by Osborn and Mook[20] the vertebræ of *Camarasaurus* are much "more compact than those of *Apatosaurus* and much stouter than those of *Amphicoelias*, *Barosaurus*, and *Diplodocus*."

Cervical Vertebræ.

The atlas is composed of four elements, intercentrum, odontoid, and two neurapophyses. They articulate in the usual manner forming a cup for the reception of the occipital condyle.

That a proatlas was present is apparently indicated by two fragmentary bones attached by matrix to the posterior part of the skull immediately above the foramen magnum and crushed down over that opening, so as to obscure its outlines, as shown in figure 3. They are too poorly preserved to permit of description.

The axis is distinctive from the other cervicals, and differs from those of both *C. supremus* Cope and *C. impar* Marsh in having a more depressed spinous process. This process, which anteriorly is low, rises at a low angle, as contrasted with the steep inclination in the two above mentioned species. The centrum is of moderate length, with an elongated pleurocentral cavity. The odontoid is free from the anterior end, which is squarely truncated. No indication is found of a separate axial intercentrum such as exists in the type of *Morosaurus agilis* Marsh.[21] The left diapophysis is broken, but enough remains to show it to have been very small. The cervical ribs for the axis and atlas, if such bones were present, are both missing.

Beginning with the third cervical, the remaining vertebræ of the neck are only partly exposed. The dorsal surfaces and the centra of the left side are all uncovered, as shown in Plate XIV. The long, attenuated, cervical ribs remain articulated with their respective vertebræ, and somewhat screen the underlying centra. This specimen shows the almost complete cervical rib-series for the first time in the

[20] Memoirs Amer. Mus. Nat. Hist., No. 8, vol. 3, pt. 3, 1921, p. 290.
[21] Gilmore, C. W., Proc. U. S. Nat. Museum, vol. 32, 1907, fig. 7.

genus *Camarasaurus.* In so far as comparison is possible, the cervicals resemble one another except in degree of development. From the third posteriorly they gradually increase in size in all dimensions. The spines on cervicals 3, 4, 5, and 6 are single, low, stout processes with flattened summits. The spines grow progressively larger posteriorly with the first notching on cervical 7; this notching becomes deeper and deeper until on cervical eleven the spine is divided into two metapophyses.

In relation to the arch the spines are posterior not median as found in other genera of the Sauropoda. The summits of the spines on cervicals 3, 4, 5, and 6 are wider than long, whereas posteriorly their dimensions are reversed. Postspinal fossæ are present behind and between the posterior zygapophyses, but deepest in those vertebræ with divided spines.

The prezygapophyses are large, flat, and wide apart with articular faces inclined toward one another. The zygapophysial laminæ, so far as they can be observed, seem to be arranged as shown in *C. supremus*, which have been described in great detail by Osborn and Mook. The diapophyses, relatively short anteriorly, grow progressively longer and heavier posteriorly. They project nearly straight out from the arch and in all instances exceed the spread of the zygapophyses. Their truncated outer ends are triangular in section. None have become coalesced with the tuberculum of the ribs.

Dorsal Vertebræ.

The dorsal series in *Camarasaurus*, as positively shown by this articulated vertebral column, consists of twelve vertebræ, exclusive of the sacro-dorsal. Osborn and Mook were correct in their conclusions as to the total number of presacral vertebræ, but erred by the inclusion of two dorsals in the cervical series. That the division between cervical and dorsal regions takes place as given above is indicated, not so much in the structure of the vertebræ themselves, as by the presence of twelve typical thoracic ribs on the right side, and with the first two ribs of the left side properly articulated by both capitulum and tuberculum with the proper facets on the first and second dorsal vertebræ respectively. The cervical rib preceding it was found nearly in position and bears no resemblance to the first thoracic rib.

The parapophysis on the first dorsal is situated on the side of the centrum in front of the pleurocœl. In the second dorsal the parapophysis is slightly higher; on the third dorsal on the lower part of the arch; on the fourth dorsal it occupies a slightly higher position; and on the fifth dorsal has apparently reached its maximum height, which is retained throughout the remainder of the series.

The dorsal vertebræ have suffered considerably from crushing, especially the transverse processes and lateral laminæ of the left side. The spines posterior to the eighth have also suffered the loss of parts. At the time of preparing this manuscript the processes of the dorsals had not been completely prepared, so that a complete account of these bones cannot be given at this time.

In so far as the centra can be observed in their articulated condition they appear to be in accord with other members of the genus in being opisthocœlous. Pleurocentral cavities are present in all and situated on the upper part of the sides of the centra. The anterior dorsals unlike those of *Diplodocus* and *Apatosaurus* are not lengthened, but are about subequal in length to those that follow. The measurements given below are made along the sides of the articulated centra and do not include the length of the ball.

No. in series	1	2	3	4	5	6	7	8	9	10	11	12
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Length	70	82	80	80	82	80	80	80	80	82	76	70
Height over all	..	..	227	230	240	255	260	..	..	..	..	..

The spine of the first dorsal is deeply cleft as in the posterior cervicals, but posteriorly they become more and more shallow, that of the sixth dorsal showing only a shallow notch. The seventh spine has an evenly low convex outline when viewed from the front. These spines have the characteristic low broad massive structure found in the other members of the genus. The lamination in so far as it can be compared at this time, is in close accord with the structure found in *Camarasaurus supremus*, which has been minutely described by Osborn and Mook.

Sacrum.

The sacrum in the present specimen is composed of five vertebræ, which have only been fully prepared on the ventral side. Coossification does not appear to have taken place between any of these centra, but all are joined to the ilia by sacral ribs. Viewed from below the four anterior centra are about subequal in length as well as in transverse dimensions; the fifth or sacro-caudal is somewhat shorter. This specimen differs from the sacrum of *Camarasaurus supremus* described by Osborn and Mook in which the caudo-sacral is subequal in size with those preceding it.

The proximal ends of the sacral ribs are coalesced with the centra, although their sutural articulation remains clearly defined. They are broad near the centra, constricted at the center, and greatly expanded at their distal ends where they meet one another to form the sacricostal yoke. Their outer ends have not yet become coalesced in this specimen.

The first rib articulates intervertebrally between the centra of the twelfth dorsal and first sacral, but more especially with the latter; the ribs of the succeeding three are articulated largely on the anterior half of the centra, but the rib of the fifth unites centrally in relation to that centrum. A very similar condition prevails in the sacrum of *Morosaurus grandis* figured by Marsh.[22] As in *Camarasaurus supremus* Cope and *M. grandis* Marsh, the ventral surfaces of the centra are transversely broadly rounded.

The sacricostal yokes are stout; on the left side, from which the ilium is missing, this yoke presents a rounded longitudinally concave surface, which, as shown on the opposite side, articulates with the ilium and enters slightly into the formation of the superior boundaries of the acetabulum. The first sacral rib contributes but slightly to the formation of the yoke, and its union with the second at the distal end is not so strong as between those more posterior. It is also thinner antero-posteriorly.

The presence of five vertebræ, entering into the formation of the sacrum, would, according to Marsh's former interpretation, exclude this specimen from the genus *Morosaurus*, which was regarded as having only four sacrals.[23] Osborn and Mook, however, have shown that in all probability there are five in all of the Sauropoda, but whether ankylosed or not depends upon the age of the individual. It is quite apparent that in this specimen we have the usual three primary sacrals with a sacro-dorsal in front and a modified caudal or sacrocaudal behind.

MEASUREMENTS.

Length of five articulated sacral centra	420 mm.
Length of four posterior sacral centra	332 mm.
Breadth across sacricostal yoke, anterior end	255 mm.
Breadth across sacricostal yoke, posterior end	300 mm.
Length of sacral spines	280 mm.

Caudal Vertebræ.

The total number of caudal vertebræ in the tail of *Camarasaurus* may now be quite certainly given as 53. In the present specimen 53 are present, the anterior 47 being preserved in regular articulated sequence. At this point, however, there is slight disarrangement, and while it cannot be positively asserted that all of the remaining elements are present, the regularity of their diminishing lengths seems to indicate that none are missing. The estimate of a total of 53 in *C. supremus* as determined by Osborn and Mook from incomplete series is therefore correct.

[22] Dinosaurs of North America, 1896, pl. 31, fig. 8.

[23] *Loc. cit.* p. 241.

Only the left side of the centra and transverse processes of the eight anterior caudals are exposed, but from the eighth posteriorly all have been worked out in full relief. The centra of caudals nine, ten, and eleven are missing, but the neural arches and spines remain articulated in their proper sequence. Transverse processes, or caudal ribs, are present on the first eight, but have disappeared entirely on the twelfth. The missing centra therefore, do not allow of an exact determination on this point. In a larger specimen of *Camarasaurus* (No. 584, C. M. Cat. Vert. Foss.), they persist as far back as the thirteenth caudal. In *Apatosaurus* these processes are found for the last time on caudal fifteen, and in *Haplocanthosaurus* on the thirteenth. These processes rapidly decrease in size posteriorly, as in the other genera mentioned.

The caudal centra in the anterior part of the tail are amphicœlous, relatively short and high, as in *Haplocanthosaurus.* These centra are somewhat constricted medially. In length they remain about subequal as far back as the twenty-second caudal, but the vertical height, diminishing rapidly at first, becomes more gradual thereafter and continues to the very tip of the tail.

As shown in the table of measurements, the reduction in length from the twenty-second vertebra posteriorly averages about 2 mm. to the vertebra. The thirty-seventh is exactly one-half the length of the first and the fifty-third is about one-fifth as long. The pointed terminal caudal is nearly twice the length of the vertebra preceding it. On the anterior third of the tail the inferior surface of each caudal is relatively broad, but this condition gradually changes posteriorly where they become regularly rounded. The chevrons are attached intercentrally, but more especially with the beveled surface of the anterior vertebra of each pair. The chevron-facets are not distinctly defined and on the anterior vertebræ in the absence of the chevrons it is quite impossible to certainly determine which vertebra of the series carried the first.

The neural arches are not disclosed in advance of the ninth vertebra at this time. The arch of the ninth is low and simple in structure, with a plate-like neural spine and apparently without terminal expansion. It is inclined slightly backward. The spinous processes decrease regularly in height and other dimensions posteriorly, becoming more rounded and gradually assuming a more nearly horizontal position in the posterior part of the series. The neural arches persist as far back as the forty-eighth caudal. The position of the arch on the anterior half of the centrum, at least from the twelfth vertebra posteriorly, appears to distinguish the caudals of *Camarasaurus* from those of *Haplocanthosaurus*, where they arise more nearly in the middle of the centrum.

The anterior half of the tail is higher than wide, but the dimensions become more nearly equal in the distal portion, where the vertebræ are nearly round in cross-section. The presence of a pointed distal caudal positively precludes the development of a long, slender, whip-lash extension, such as has been found in *Diplodocus* and *Apatosaurus*. Measured along the side of the centra the complete series has a total length of about 23.55 mm. or about 7 ft., 9 inches.

MEASUREMENTS OF CAUDAL VERTEBRÆ.

No. in series	Length of Centrum	Height over all	No. in series	Length of Centrum	Height over all	No. in series	Length of Centrum	Height over all
	mm.	mm.		mm.	mm.		mm.	mm.
1	64		24	55	95	47	22	—
2	63		25	55	90	48	19	—
3	62		26	53	85	49	18	11
4	61		27	52	80	50	15	9
5	62		28	50	72	51	14	9
6	62		29	49	63	52	13	8
7	65		30	47	60	53	20	7
8	59		31	45	58			
9	–		32	43	57			
10	–		33	41	50			
11	–		34	39	—			
12	55	152	35	37	—			
13	57	145	36	35	45			
14	57	140	37	32	43			
15	58	135	38	30	38			
16	58	130	39	29	36			
17	58	130	40	29	35			
18	60	120	41	27	—			
19	59	115	42	26	—			
20	60	110	43	25	—			
21	58	—	44	25	—			
22	58	105	45	24	—			
23	56	102	46	22	21			

Chevrons.

The total number of chevron-bones in the tail of *Camarasaurus* cannot be certainly determined from this specimen. All are missing back to the fourteenth caudal, but from this point to the thirtieth the articulated series is preserved *in situ*. That there were at least three more is shown by those present but slightly displaced on the thirteenth to the thirty-second caudal. Assuming that Osborn and Mook are correct in regarding the first caudal as carrying the first chevron, there would be thirteen missing from the anterior part of the tail, or, with the nineteen actually present, the complete series of chevrons would consist of thirty-two elements.

The fourteenth chevron is Y-shaped, with a shaft which curves backward. It has a greatest length of 90 mm. Posteriorly they become progressively shorter, with a more and more decided bending back of the distal extremity. On the twenty-second vertebra the chevron presents a widened blade of putty-knife shape, but beginning with the twenty-fourth this blade begins to develop an anterior projection, and in the last of the series the anterior and posterior projections are about subequal. The twenty-third chevron is 40 mm. long; the twenty-seventh is 28 mm. in length.

Cervical Ribs.

The cervical ribs of *Camarasaurus* as shown by this specimen for the first time, constitute one of the characteristic features of its skeletal anatomy. Reference is made to their great length and the slenderness of their shafts. The rib of the seventh vertebra, which is the longest of the series attains a length of 375 millimeters, and its attenuated end reaches a point near the forward end of the centrum of cervical 11. The fifth rib measures 318 mm.; the sixth rib measures 325 mm. in length and its distal termination is slightly in advance of the diapophyses of cervical 9. The anterior ribs are long, but posteriorly they shorten rapidly. This type of cervical rib is in striking contrast to the heavy and relatively short ribs in *Apatosaurus*, or the relatively short, but more slender ribs of *Diplodocus*, none of which overlap more than the succeeding cervical.

In large adult individuals of *Camarasaurus* the cervical ribs are usually ankylosed by their tubercular processes with the diapophyses of the vertebræ, but in this specimen all remain distinct, another indication of its immaturity.

There is no appreciable extension of the rib forward in front of the tubercular process as in *Diplodocus*, and to a less extent in *Apatosaurus*, this end being quite squarely truncate. The shafts of the ribs extend backward at right angles to the tubercular and capitular processes and taper to a long, slender rod whose distal extremities have a tendency to turn outward.

Eleven of the cervical ribs of the left side were preserved articulated, beginning with the axis. These have the following lengths commencing with the fifth: fifth, 318 mm.; sixth, 325 mm.; seventh, 375 mm.; eighth, 320 mm.; ninth, 170 mm.; tenth, 146 mm.; twelfth, 130 mm. The first thoracic rib increases to a total length of about 510 mm.

Thoracic Ribs.

On the lower or right side of the skeleton, undisturbed in the matrix, are twelve thoracic ribs. These are preserved in regular sequence and show for the first time in the genus *Camarasaurus* the total number of thoracic ribs as well as a correct idea of their proper arrangement. The proximal ends extend into the matrix beneath the line of dorsal vertebræ and are not to be observed at this time. The second rib, due to a fracture passing through the vertebral column, is properly articulated with the second dorsal, and it is presumed from the regularity of their spacing that all remain articulated with their respective vertebræ. All of these ribs, with the possible exception of the first, are considerably flattened and give no clue as to the proper curvature of the thoracic walls.

It is the presence of these twelve undoubted thoracic ribs which certainly determines the number of dorsal vertebræ in this genus. This count does not include any dorso-sacral rib, and it seems very doubtful that this vertebra had a free rib.

The first rib is straight and relatively short, its distal extremity ending behind the scapula, at a point opposite the most constricted part of the shaft. The second rib of the left side has a greatest length measured over the curve of 620 mm. Since the right scapula in this specimen is regarded as having been retained in its proper angle in relation to the vertebræ and thoracic ribs, in any articulated skeleton the distal end of this rib would not be visible below the lower border of the blade, in a lateral view. The upper or exposed part is wide transversely, but near the middle of the shaft is subround, becoming flattened and widened antero-posteriorly as the truncated distal end is approached. The character of this end strongly suggests that it was attached to the sternum by a cartilaginous rib. It certainly bears no resemblance to the sharply pointed transitional ribs found between the true cervical and dorsal ribs in the *Camptosauridæ*, and which give rise to differences of opinion as to which series they should properly be assigned.

The first and second ribs of the left side are also present and articulated with the diapophyses, but they have suffered loss of distal portions of the shafts. The right rib, however, is complete and is nearly eight inches (200 mm.) longer than the first. Proceeding posteriorly from the second the ribs become progressively longer, and heavier. In these respects they reach their maximum development in the fifth. The sixth to the eighth rib remain about subequal in length, but their shafts grow progressively narrower. These ribs, including the next two, are very slender. The ninth is slightly shorter than the tenth. The remaining ribs shorten rapidly by decided steps. The distal end of the eleventh terminates slightly below the level of the point of the articulated ilium. The twelfth has the proportions of the eleventh, but measures 100 mm. shorter. It curves forward in front of the iliac border, and suggests that in an articulated skeleton its distal portion would be in front of the ilium and not behind it, although that is the position of similar ribs in mounted skeletons of *Apatosaurus* and *Diplodocus*. Brown[24] has shown that the posterior ribs in *Monoclonius* also curve forward to positions in front of the ilia.

The Pectoral Girdle.

The pectoral girdle is represented by both scapulæ, coracoid, and one complete sternal plate, and the anterior portion of the other.

The scapula is of the typical *Camarasaurus* type, being relatively short, with broadly expanded proximal end and with the upper or distal end strongly expanded in an anterior direction. The coracoid is subquadrangular as in the other members of the genus.

Especially interesting is the preservation of the right scapula and coracoid in somewhere near their natural relations in reference to the thorax and the vertebral column. Since all the other bones of the right side, have been retained in their proper articulated relationships, there seems no reason for not regarding the scapula as being similarly preserved, except that it is quite apparent (See Plate XIV) that the anterior part of the body has been thrust upward away from the attached fore limbs. Assuming these deductions to be correct, this specimen furnishes the first evidence obtained of the articulation of the shoulder-blade in the sauropodous dinosaurs. This is especially important as there has been a great diversity of opinion as to its position and angulation as expressed in articulated skeletons, and also in pictorial restorations of these animals. The latest and most radical departure from previously held views being the restoration by Osborn and Mook of *Camarasaurus supremus*[25] in which the scapula has been given a more nearly perpendicular position bringing about a great elevation of the shoulders. The evidence furnished by the present articulated specimen showing the scapula as found in position, is quite opposed to such a posture. It shows the scapula as having the blade in a much more horizontal position. The whole scapula is probably lower on the side of the thorax than shown in any restoration or mounted skeleton of this group of dinosaurs. The first rib crosses the upper border at about the center of the narrowest part of the shaft, and the upper truncated end reaches posterior to the fifth rib. This end is 370 millimeters distant from the lower anterior border of the ilium of the same side.

[24] Bull. Amer. Mus. Nat. Hist. vol. 37, 1917, p. 294, pl. XIII.

[25] Memoirs Amer. Mus. Nat. Hist., n. s., vol. 9, pls. 83–84, also fig. 28.

Though highly desirable to have verification of this evidence, past experience has shown that information furnished by articulated skeletons *in situ*, is far more to be relied upon than any number of expert opinions, based on analogies deduced from the study of living reptiles. This information concerning the articulation of the scapula is one of the outstanding contributions of the present specimen to a more exact knowledge of sauropod anatomy.

Sternal Plates.

The sternum is represented by one complete plate provisionally identified as the right and the anterior portion of the opposite. Both were found out of position in the rock above the caudal vertebræ. The complete plate shown in fig. 5, is suboval in outline, as in *C. supremus*. This plate has a thickened end which looks forward and outward and it is this border which probably articulated with the process of the coracoid, the distal is thinner and with many indentures for the attachment of the cartilaginous ribs. The internal and external borders are subequal in thickness, but the side regarded as median has a straighter border.

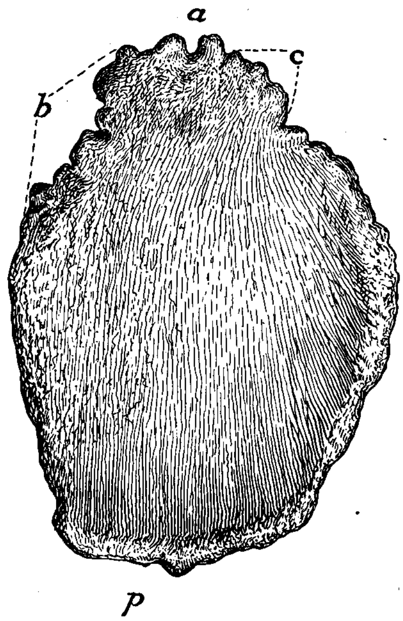


Fig. 5. Right sternal plate of *Camarasaurus lentus* (No. 11,338 C. M. Cat. Vert. Foss.). Superior view, one-fourth natural size. *a*, anterior end; *b*, margin next to median line; *c*, coracoid border; *p*, posterior end.

While there may be some doubt as to which side this plate belongs, the thickened extremity certainly identifies it as being the anterior end, as shown by the sternal plates of *Monoclonius* found in position by Brown.[26] The dorsal surface of the plate is shallowly concave from side to side, while the ventral surface is slightly convex in the same diameter. The slight constriction of the lateral borders near the posterior ends seems to show that Marsh has incorrectly identified the posterior ends of the sternal plates of *C. grandis* as illustrated by him in fig. 30, p. 179, in "Dinosaurs of North America."

This plate has a greatest antero-posterior diameter of 283 mm.; a greatest diameter of 200 mm.

Fore Limb and Foot.

All of the bones of both fore limbs are preserved and to a large extent remain properly articulated. The head of the right limb remains in the glenoid fossa.

[26] Brown, B., Bull. Amer. Mus. Nat. Hist. vol. 37, 1917, p. 291, figs. 3 and 4.

The left limb lies in the sandstone matrix above and slightly forward of the right. The humeri have their anterior surfaces directed strongly toward one another, but whether this fact will contribute any information as to the proper pose of the front limbs I am unprepared to say at this time. The humeri are stout, with expanded ends more especially the proximal, with prominently developed deltoid crest. The condyles are rather weakly developed, and the olecranon fossa is shallow. In length they are slightly more than half as long as in the type of *Morosaurus grandis*. The width of the proximal end, as compared with the length, is considerably greater than in either *Camarasaurus supremus* Cope, or *C. grandis* (Marsh).

The ulna is moderately stout at the proximal end deeply concave anteriorly for the reception of the proximal portion of the radius. In the shaft the ulna is stouter than the radius, but tapers toward the distal end, so that the distal ends of these two bones are about subequal in size.

The articulated radius crosses from the front at the proximal end to the side at the distal end of the ulna. The two slightly expanded ends of this bone are about equal in size.

In relation to the humerus the lower limb bones of this specimen are relatively longer than in the type of *Morosaurus grandis*, but whether this is a constant difference or due to the immaturity of the individual yet remains to be determined. The lack of rugoseness on the ends of the limb bones and the moderate development of their processes clearly indicates the immaturity of the present specimen.

Carpus and Forefoot.

Both articulated fore feet are present, but neither one is completely preserved, though from a study of both it has been possible to determine nearly the entire structure of the manus.

The carpus in *Camarasaurus*, as is now quite certainly established, consists of a single large, compact, flattened, block-like radiale. Such a bone is present in both limbs, and in both instances occupy precisely similar positions in relation to the other elements of the limb and foot, *i. e.* above metacarpals I and II and below the distal end of the radius. Additional evidence in support of this view is furnished by an articulated forefoot in the U. S. National Museum assigned to *Morosaurus agilis* by Marsh, and figured by him.[27] It has a single element similarly articulated. That it has *Camarasaurus* affinities is clearly shown by comparison with the feet of the present specimen. In 1901 Riggs[28] described and figured a manus identified

[27] 16th Ann. Rept. U. S. Geol. Survey, pt. I, 1896, pl. 37, fig. 1.

[28] Field Columbian Museum, Pub. 63, vol. I, 1901, Geol. Sur. p. 276, pl. 41, fig. 1.

as pertaining to *Morosaurus grandis* also having a single carpal and occupying the same relative position as in the feet of the specimen here discussed. In restoring this foot, however, Riggs introduced a second large element.

Osborn[29] has illustrated feet ascribed to *Morosaurus*, but in each instance there are two large carpal elements of about equal proportions. The justification for this arrangement is not presented, so that in the light of the present evidence it would appear either that Osborn was in error, or else the feet were wrongly identified. In this connection it should be mentioned that a small flattened ossification was found near the left wrist of the present specimen, but, as it was evidently out of position, one cannot be altogether certain where it belongs in the carpus.

On the evidence of the four articulated fore feet discussed above, it would now seem to be an established fact that the carpus in *Camarasaurus* consists of a single element, the radiale, which always articulates with metacarpals I and II, and possibly a smaller bone whose precise position is yet unknown. This feature of the carpus in *Camarasaurus* will be of assistance in distinguishing it from *Apatosaurus* with its single large medially located disk-like carpal and from *Diplodocus* with its two block-like carpal elements.

The metacarpus consists of five functional metacarpals. All are present in each foot of this specimen, the right having the palmar view exposed; the left with part of the front aspect. The proximal ends vary in form, the median three being roughly triangular and all are closely applied to one another at this end. The distal ends are all expanded transversely. Metacarpal I is the shortest and stoutest of the series with the distal end slightly oblique and shallow and broadly grooved. Metacarpal II is longest. Metacarpal V is reduced. When articulated the metacarpals are broadly rounded viewed from the front, and it would seem they would carry the weight evenly.

Only the first digit is provided with a claw-like ungual. The evidence furnished by many articulated fore feet in various museums, supported by the present specimen, further establishes the fact that in the Sauropoda there is but one ungual, and that a relatively small one, carried on the pollex. The digital formula as established on this specimen would be 2, 1, 1, 1, 1. Digit I of the right pes has two articulated phalanges, the last one a slightly curved ungual; digit II and III of this foot carry a single phalanx each; those of IV and V are missing. The left foot has proximal phalanges on the I and V digits possibly a disarranged phalangial may pertain to digit IV. A small button-like ossification in the matrix lateral to

[29] Bull. Amer. Mus. Nat. Hist. vol. 14, 1901, fig. 3; Idem. vol. 20, 1904, fig. 1.

the proximal phalanx of digit V may represent the terminal phalanx of that toe, but of this one cannot be certain.

Riggs[30] has especially drawn attention to the oblique direction of the claw of the first digit brought about by the bevelling of the inferior facet of metacarpal I and the two facets of the proximal phalanx in such a manner as to give the articulated claw an oblique outward and backward direction. This condition is fully substantiated in the present specimen.

Pelvic Girdle.

The pelvic arch is represented by the articulated ilium, pubis, and ischium of the right side, and the pubis of the left side. The left ilium and ischium are missing. In the present position of the skeleton the right ilium is almost entirely hidden from view by the overlying sacrum, except a portion of its anterior extremity and the acetabular border. The parts exposed are in conformity with those of the described ilia of this genus.

The pubis is short and in its general conformation is quite in accord with other pubes of *Camarasaurus*. It lacks the massiveness of this bone in the larger species, but this difference is no doubt due to the immaturity of the individual. The pubic foramen is open posteriorly as in *C. lentus* whereas in *C. supremus* Cope and *C. grandis* (Marsh) it is entirely enclosed. Since similar conditions are found among specimens of *Camptosaurus*, where an open foramen is always associated with juvenile characteristics, I am inclined to the opinion that this difference is to be explained in the same way.

The right ischium has the characteristic long, slender shaft without distal expansion so distinctive of the genus *Camarasaurus*. The proximal end is expanded and closely approximates the form of the *C.* (*Morosaurus*) *lentus* ischium figured by Marsh.[31]

These bones of the pelvis are less massive, and lack the heavy and rugose development of their articular ends and surfaces found in the larger members of the genus.

Hind Limb and Foot.

The right hind limb and foot are complete and articulated, except for the loss of a few smaller elements of the pes. The femur of the left leg is shifted out of position and was found lying in the matrix below the posterior part of the neck. The fibula of this side was displaced, but the tibia and nearly complete foot was preserved in its natural relations to the remainder of the skeleton.

[30] *Op. cit.* p. 276.

[31] 16th Ann. Rept. U. S. Geol. Survey, pt. I, 1896, pl. 36, fig. 1.

The head of the right femur remains in the acetabulum and furnishes irrefutable evidence in support of those advocating an upright mammalian-like articulation of the hind limb in the sauropodous dinosaurs, as opposed to the lizard-like posture advocated by Tornier,[32] Hay[33] and others. The head of the femur is inserted straight into the acetabulum at right angles to the longer axis of the shaft. That it could not be articulated otherwise is indicated by measurements, which show the antero-posterior diameter of the acetabulum (175 mm.) to be less than the transverse diameter of the proximal end of the femur (220 mm.). This fact absolutely disposes of the proposed articulation of the femur suggested by Hay. The bone of the distal half of the right femur has been somewhat altered by crushing, but the left is quite perfectly preserved. It is relatively short and broad, as compared with those of other sauropod genera. The fourth trochanter is moderately developed, and is entirely on the proximal half of the bone, whereas in *C. supremus* the apex of its crest is exactly in the middle of the shaft. The condyles have a moderate development, and there is a decided anterior intercondylar groove.

The tibia is massive, and slightly less than two-thirds the length of the femur. The proximal end is broad transversely. The external flange, which is developed in front of the fibula, is thickened and curves decidedly backward. The distal end is less expanded than the proximal end and has the usual notching for the astragulus.

The right fibula remains articulated, but it has not been sufficiently developed to show its characteristics.

Both astragali are preserved and both are free from the tibiæ. Viewed from above the inner end is obtusely pointed, the posterior border nearly straight, the anterior irregularly convex. The inferior surface is slightly convex anteroposteriorly. The external end is grooved longitudinally for the fibula. A small rounded ossification attached by matrix close to the outer end of the left astragalus may represent either the calcaneum or a tarsale of the distal row.

The hind foot of the left side (See Pl. XV) is the most perfectly preserved. The five metatarsals are articulated, and the phalanges of the first three digits are all present and but slightly disturbed. It shows that the first three toes of the pes bore terminal claws, with a phalangial formula of 2, 3, and 4. The other phalanges are missing, while the right foot shows a proximal phalanx on digit IV.

The metatarsals closely resemble those of *Morosaurus grandis*, figured by Marsh

[32] Sitzungsber. Geo., Naturforsch. Freunde. zu. Berlin, 1909, pp. 293–209, pl. 2.

[33] Proc. Wash. Acad. Sci., XII, 1910, No. 1, pp. 1–25, text-figs. 1–7.

(*Dinosaurs of North America*, pl. 29, fig. 2) except for their much smaller size. Metatarsal I is shortened and the stoutest of the series.

COMPARATIVE MEASUREMENTS.

	Camarasaurus lentus No. 11338, C. M.		*C. grandis* Type, Yale Mus.	*C. supremus* Am. Mus. Nat. Hist.
	Right	Left		
Pectoral Girdle and Fore Limbs:				
Scapula, length			1093	1665
Scapula, width widest portion of blade	200		635	970
Scapula, width narrowest portion of blade	88			340
Coracoid, length				725
Humerus, length	450	426	864	1135
Humerus, transverse diameter proximal end	—	210	381	500
Humerus, transverse diameter distal end	—	160	260	360
Ulna, length	300	310	628	—
Ulna, transverse diameter proximal end	—	108		—
Ulna, transverse diameter distal end	64	65		—
Radius, length	298	292		—
Radius, transverse diameter proximal end	—	73		—
Radius, transverse diameter distal end	—	72		—
Metacarpal I, length	107	104		—
Metacarpal II, length	140	—		245
Metacarpal III, length	135	134		—
Metacarpal IV, length	120	122		—
Metacarpal V, length	109	107		—
Sternal bone, length	283	—		675
Sternal bone, greatest width	200	—		330
Pelvic Girdle and Hind Limb:				
Ilium, length				1150
Pubis, length	385	410		980
Pubis, width proximal end	185	155		415
Pubis, width distal end	125	148		460
Ischium, length	380	—	488	1160
Ischium, width of proximal end antero-posteriorly	110	—		
Ischium, width of distal end, transversely	56	—		185
Femur, length	555	580	1050	1270
Femur, transverse diameter proximal end	—	208	340	450
Femur, transverse diameter distal end	154	182	290	440
Tibia, length	350	350		1040
Tibia, transverse diameter proximal end	135	145		415
Tibia, transverse diameter distal end	119	115		355
Astragalus, transverse width	109	110		380
Metatarsal I, length	70	70		—
Metatarsal II, length	—	90		—
Metatarsal III, length	—	88		225
Metatarsal IV, length	—	80		—
Metatarsal V, length	—	60		—

The linear proportions of the several segments of the skeleton are as follows:

	mm.	In
Skull and jaws	330	13.2
12 Cervical vertebræ	1020	40.4
12 Dorsal vertebræ	952	38.0
5 Sacral vertebræ	420	16.8
53 Caudal vertebræ	2355	94.2
Length of combined axial skeleton	5077	203.0
Estimated height of back bone at hips	1240	49.6

Reconstructed Skeleton of Camarasaurus.

On Plate XVII is presented a reconstruction of the skeleton of *Camarasaurus* based on the magnificent specimen described in the preceding pages. It bears the distinction of being the first restoration ever made of a sauropod dinosaur based exclusively upon the remains of a single individual.

The restoration represents the animal in a quadrupedal pose as viewed from the left side. It at once reveals the unusual proportions of *Camarasaurus*, in having a relatively short neck, long body and deep thoracic cavity. It is to be regretted however, that such a disparity of proportions are found between it and the artistic reconstructions and restorations of *Camarasaurus supremus* so recently presented by Osborn and Mook,[34] as to render the latter unfit for further use in depicting the characteristic proportions of the genus *Camarasaurus*.

On the evidence of this complete articulated back bone, the relative proportions of the several segments of the vertebral column may now be considered as absolutely determined.

One of the unusual features brought out in the Osborn-Mook restoration was the elevation of the shoulders, making it the highest point in the backbone. This was brought about by placing the scapula in a nearly vertical lizard-like position.

The evidence afforded by the present specimen does not support such a conclusion and in the present restoration the scapula is given a more horizontal attitude overlying the sides of the ribs in conformity with the evidence of the right scapula, which was found in place, as shown in Plate XIII.

Anything less than a vertical position of the shoulder-blade necessarily results in a lowering of the shoulders below the level of the sacrum, thus bringing the contour of the back into conformity with other sauropod restorations, such as those of *Apatosaurus* and *Diplodocus*. Past experience has shown that evidence furnished by articulated parts found *in situ* are far more to be relied upon for structural features than any number of "expert opinions," and this specimen appears to furnish another example of that fact.

[34] Memoirs Amer. Mus. Nat. Hist., vol. 3, pt. III, 1921, pls. 83, 84, and 85 and text fig. 28.

Another departure in this reconstruction from the usual restoration is the elevation of the anterior caudal region, which carries the tail well out over the ischia before it commences to droop toward the ground. This innovation was adopted upon the evidence furnished by the mounted skeleton of *Apatosaurus louisæ* Holland in the Carnegie Museum, where a similar elevation is developed from the actual articulation of the bones. The correctness of this pose in *Apatosaurus* is further substantiated by a study of two *Diplodocus* skeletons, both of which indicate that a similar condition exists in that genus.

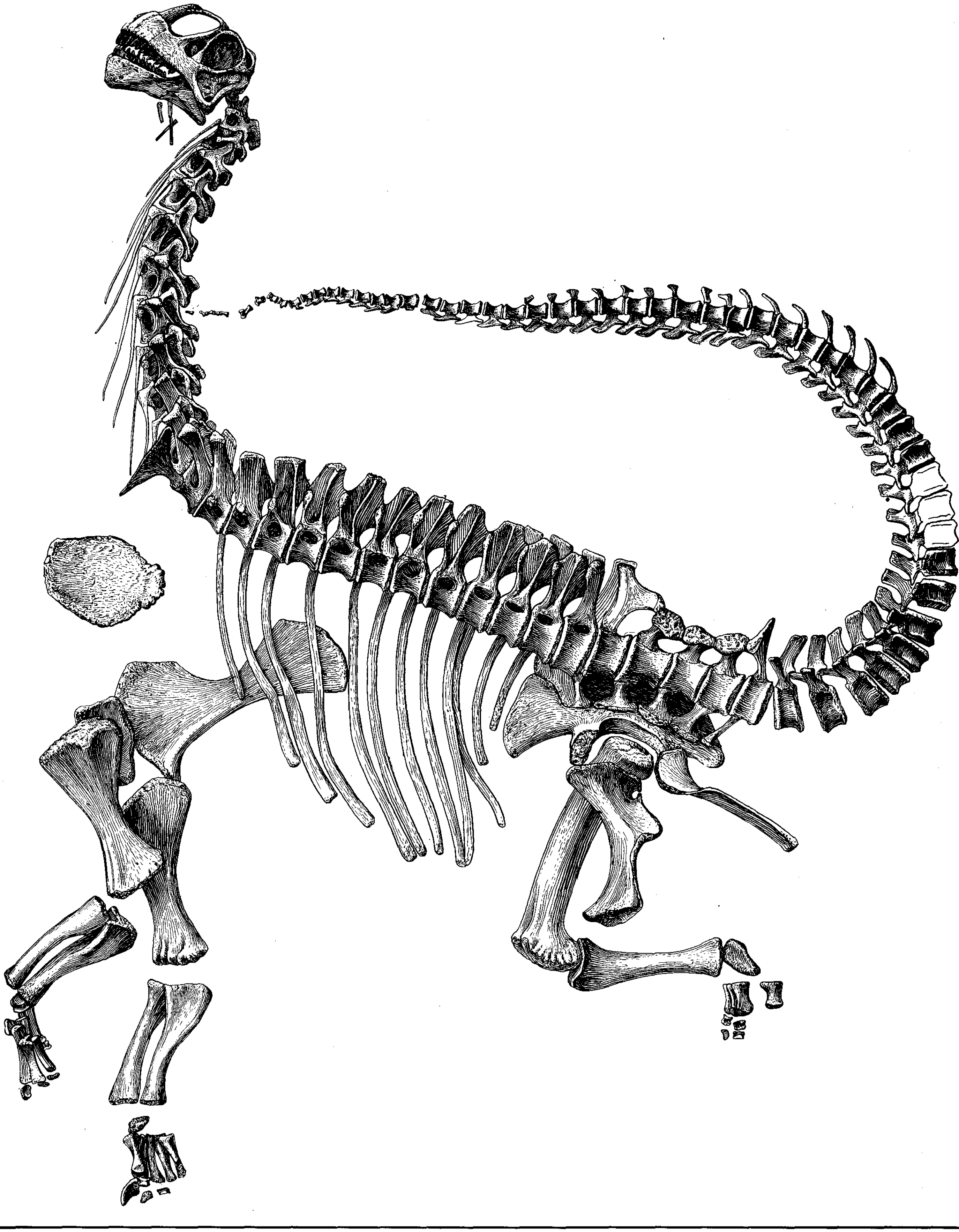
Reference is first made to the mounted skeleton of *Diplodocus carnegiei* Hatcher in the Carnegie Museum, which is obviously incorrect in this region, as shown by the V-shaped space between the centra of the posterior sacral and first caudal; the non-articulation of their zygapophyses; and the wide space between the tops of their respective spinous processes. A skeleton of *Diplodocus* now being prepared in the U. S. National Museum in which the sacrum and anterior caudals were found articulated shows that the faces of the centra mentioned above are parallel and that the tops of the spines of the vertebræ are uniformly spaced, and, when viewed from the side, the curve of the caudals corresponds precisely with the mounted *Apatosaurus* tail so skillfully articulated by Mr. A. S. Coggeshall. From the above evidence it was considered reasonable to believe that *Camarasaurus* probably had a similar upward arcuation of the tail.

The thoracic cavity is unusually deep, and, although some allowance has been made for their having been lengthened by the straightening out of their natural curves, it may be that they are still too long, as represented in the restoration.

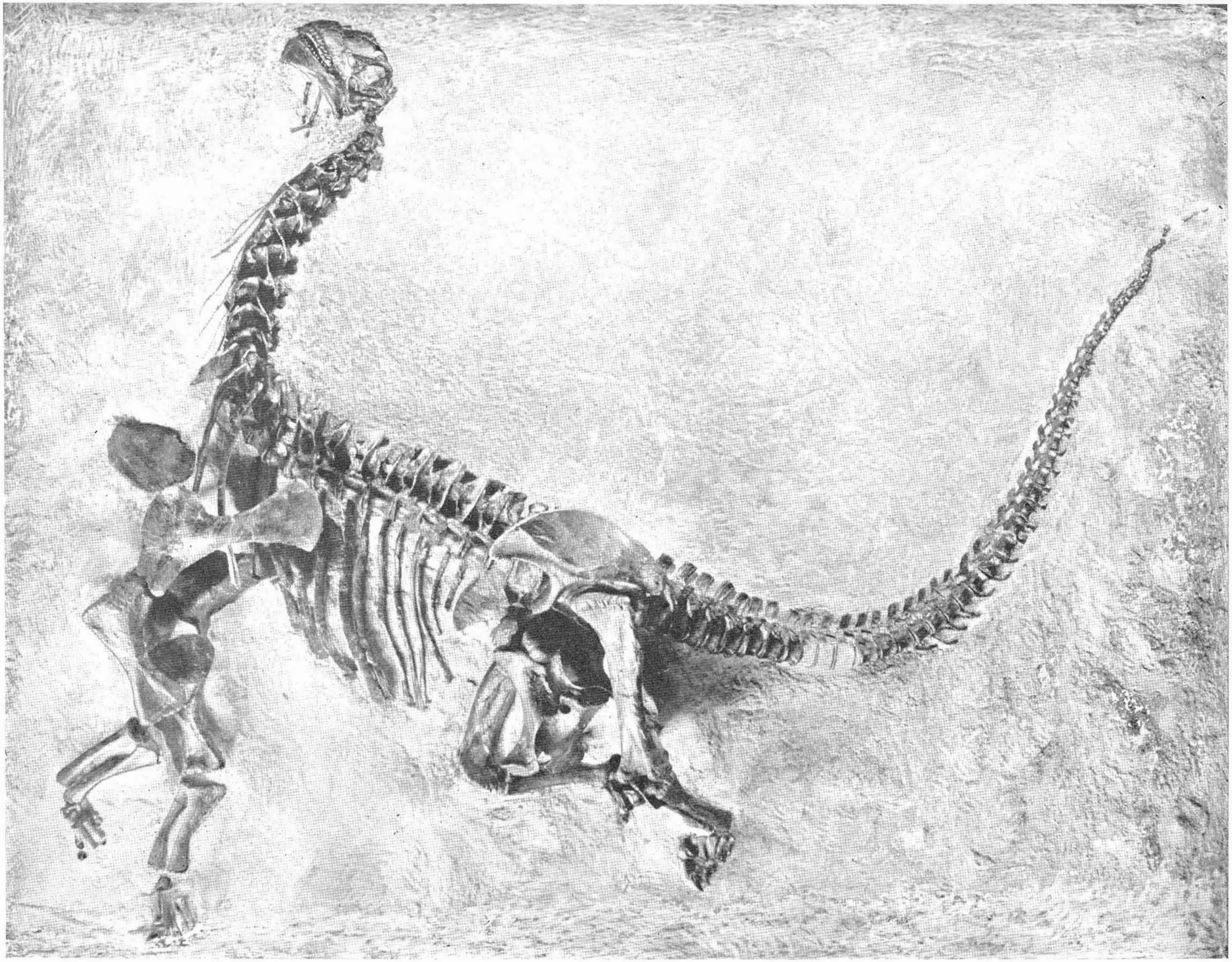
Another interesting feature brought out in this reconstruction is the great length and slenderness of the cervical ribs. In the matter of length they rival those of the recently described *Uintasaurus douglassi* Holland.[35]

In the present pose the neck curves upward from the body with the head slightly elevated in relation to the neck. The relatively low spines of the vertebræ, the stout limbs, and the slender ischia are all features characteristic of the genus, and, while the actual articulation of the bones of a skeleton of *Camarasaurus* will probably show the present reconstruction to be in error regarding some details, it is believed to give a fairly accurate representation of this interesting animal.

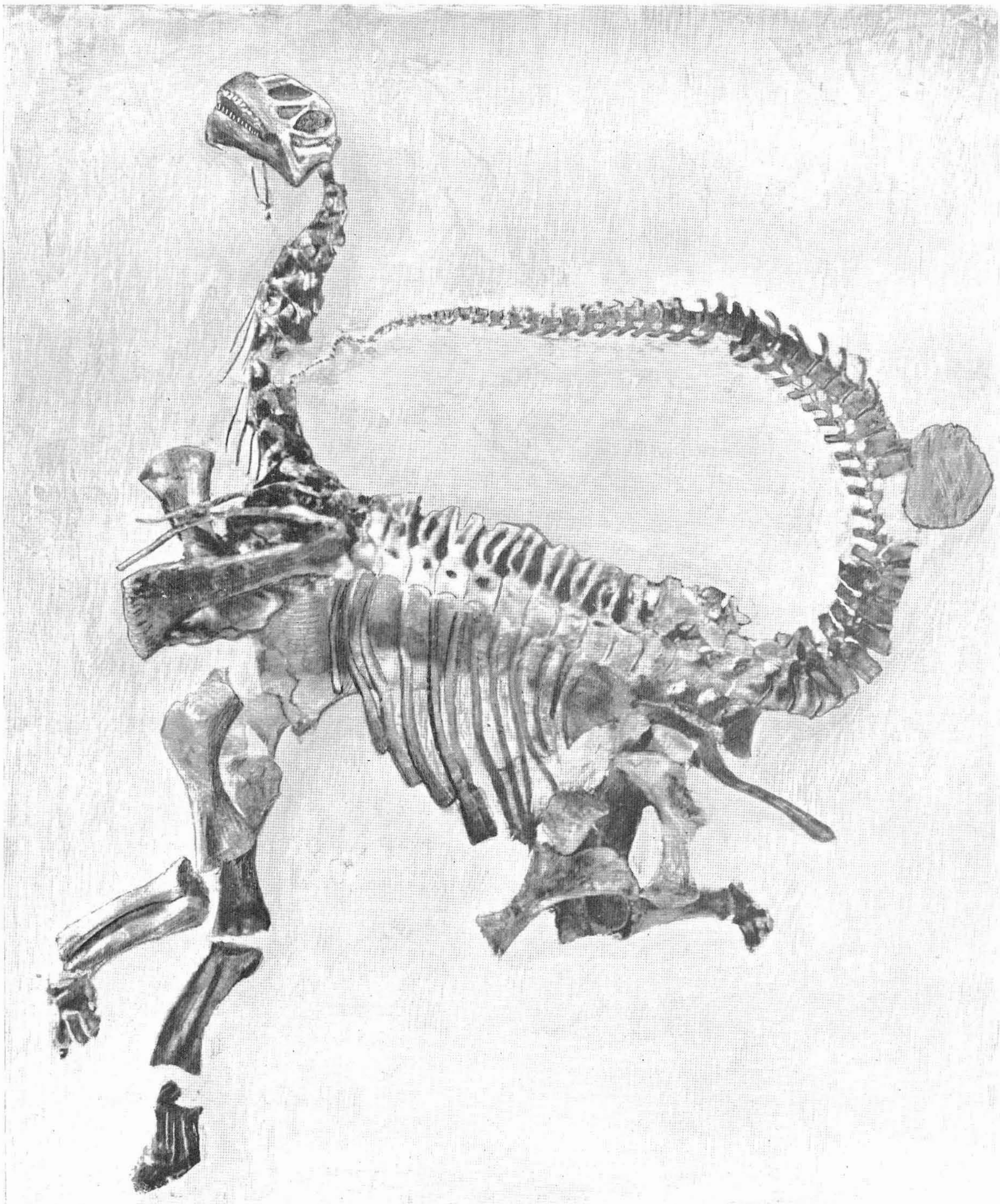
[35] Annals of the Carnegie Museum, XV, 1924, pp. 119 to 138. Pls. X to XIII.



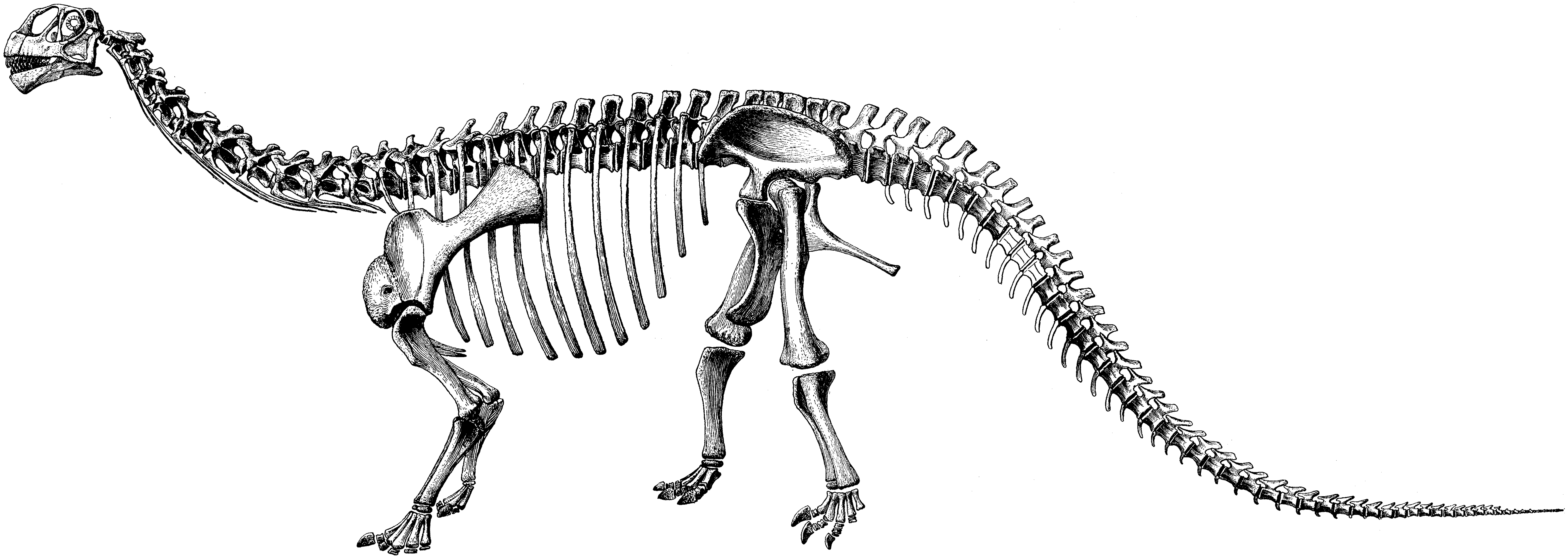
Skeleton of *Camarasaurus lentus* (Marsh). (C. M. Cat. Vert. Foss., No. 11,338.) One-twelfth natural size. Drawing by Sidne
entice, designed as a key to plate XIII. Left femur at base of neck, left thoracic ribs, left scapula, left tibia, foot, and left pub
t indicated in this figure. Sternal plate, originally at left of tail, shown beneath the neck.



Skeleton of *Camarasaurus lentus* (Marsh). (C. M. Cat. Vert. Foss., No. 11,338.) From a photograph by Arthur S. Coggeshall, showing the skeleton as now mounted and displayed. About one-eighteenth natural size. A few displaced bones have been re-articulated; the left ilium of another individual has been introduced; the tail has been straightened.

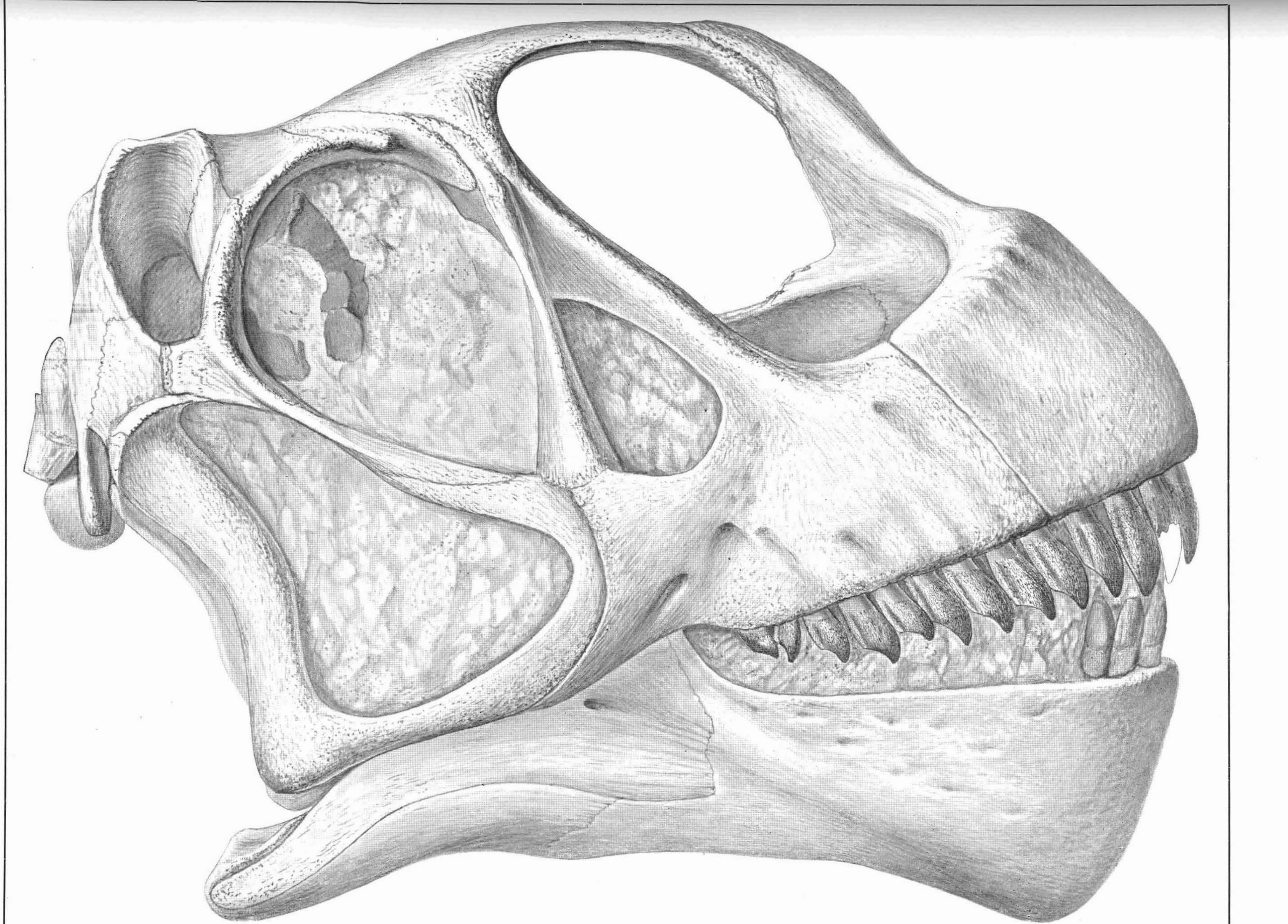


Skeleton of *Camarasaurus lentus* (Marsh). (C. M. Cat. Vert. Foss., No. 11,338.) In position as found. One-fifteenth natural size. Photographed by Arthur S. Coggeshall.



Restoration of skeleton of *Camarasaurus lentus* (Marsh).

This restoration is based on the nearly complete skeleton shown in plates XIII and XIV. It is the first restoration of a sauropod dinosaur to be made entirely on the evidence of a single individual. Restoration by Mr. Sidney Prentice under the direction of the author. About one-tenth natural size.



Skull of *Camarasaurus lentus* (Marsh). (No. 11,338, C. M. Cat. Vert. Foss.) View of right side. Slightly displaced and incomplete sclerotic ring shown at right of orbital cavity. About two-thirds natural size.