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(With Four Plates)

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In 1942 an expedition from the Cleveland Museum of Natural History, under the leadership of Dr. D. H. Dunkle, explored the Lance formation in Carter County, Mont. Among the important discoveries resulting were the well-preserved skull and jaws of a carnivorous dinosaur.

The specimen clearly pertains to the Deinodontidae, a family previously represented in the Lance fauna only by the gigantic *Tyrannosaurus.* That other deinodonts occurred in this fauna has long been known from scattered teeth and phalangeal bones found from time to time during the 50 years or more that the Lance has been searched for fossil remains. The present discovery of an identifiable specimen is therefore of considerable interest. Through the courtesy of Dr. Dunkle this specimen has been placed in my hands for study and description.

Family DEINODONTIDAE Cope

The Deinodontidae includes all of the large Upper Cretaceous carnivorous dinosaurs such as *Deinodon, Tyrannosaurus, Gorgosaurus,* and *Albertosaurus.* The affinities of the present specimen appear to be in the genus *Gorgosaurus,* as shown by many close similarities to *G. libratus* and *G. sternbergi,* thus greatly extending the geologic range of *Gorgosaurus* from the Belly River into the Lance. On the basis of its geologic occurrence, smaller size, and slight differences in skull structure, it becomes necessary to describe it as a new species, for which the name *G. lancensis* is proposed. The specific name is in reference to the Lance formation in which the type specimen was found.

[1] Published posthumously. Mr. Gilmore died September 27, 1945.

Although following Matthew and Brown (1922) in their conception of the availability and scope of the family Deinodontidae, it is well to point out that the genotype, *Deinodon horridus,* was founded by Leidy (1856) exclusively upon detached teeth, a fact well known to both of the above authorities, but who make the dogmatic statement that the family Deinodontidae was "based upon an unquestionably valid genus." With this conclusion I disagree for, with the accumulating evidence of later years, it becomes more and more apparent that genera of Upper Cretaceous carnivorous Dinosauria cannot be differentiated on tooth characters alone. It therefore appears highly probable that the use of the genus *Deinodon* may have to be abandoned and with it, following nomenclatural procedure, the family term Deinodontidae.

Genus GORGOSAURUS Lambe, 1917

Genotype.—*Gorgosaurus libratus.*

GORGOSAURUS LANCENSIS, new species

Type.—C.M.N.H. No. 7541. Skull and lower jaws. Collected by D. H. Dunkle, August 16, 1942.

Locality.—SE$\frac{1}{4}$, sec. 11, R. 61 E., T. 4 S., Sand Creek, Carter County, Mont.

Horizon.—Upper Cretaceous, Lance formation, Hell Creek member.

The type and only specimen is a nearly complete skull with tightly articulated lower jaws. It has suffered the loss of the squamosal, postfrontal, quadratojugal, and the upper half of the quadrate of the right side; there is some disarrangement of the bones of the palate, and many of the teeth are either missing or incomplete. Otherwise the skull is in well-preserved condition. The coalescence of many of the sutures strongly suggests the adult age of the individual.

So close is the union between upper and lower jaws that not only is the lower dentition wholly concealed, but the very grave danger of doing permanent injury to the specimen prevents any attempt to separate them.

In size the skull is smaller than the cranium of the type of *Gorgosaurus sternbergi* with which, in several respects, it appears to have the nearest affinities. Unfortunately for the present purposes the type of *G. sternbergi* has never been adequately described, and its original specific characterization was very meager. Furthermore, a single figure of the mounted skeleton published by Matthew and Brown

(1923, fig. 4) constitutes the only published illustration of this type. Since the skeleton is on exhibition and under glass that cannot be readily removed, direct comparison or study of the actual skull is practically out of the question at this time. In plate 4, figure 2, is shown a side view of the skull enlarged from the one and only negative of this specimen and generously placed at my disposal by Dr. E. H. Colbert.

Matthew and Brown (1923, p. 7) distinguished *Gorgosaurus sternbergi* as follows: "It is of smaller size and more slender proportions than the *G. libratus.* The jaws are much less massive and the muzzle is more slender, the maxilla more elongate and shallow, the orbital fenestra more circular, the tibia is considerably longer than the femur." In most of the skull characters mentioned, the cranium is in agreement with the specimen now before me. In slenderness of the muzzle it is intermediate between *G. libratus* and *G. sternbergi.* The dental formula appears to be the same in all three species.

It should be pointed out, however, that this apparent slenderness of muzzle in the type of *G. sternbergi* (see pl. 4, fig. 2) is greatly exaggerated by the downward crushing of the nasal region. Restored to its normal profile this slenderness becomes much less noticeable. In its smaller size, elongate shallow maxillary, and rounder orbital fenestra, *G. lancensis* appears to have its closest affinities with *G. sternbergi.* There are some minor differences in skull structure, but none is regarded of specific significance. Such differences as are observed in the lateral temporal fenestral region are clearly due to postmortem distortion. The quadrate having been crushed forward and upward narrows the fenestra and otherwise alters the natural angulation of the elements composing this part of the skull.

In the absence of detailed knowledge of the cranial characteristics of the two described species, it is quite impossible at this time, on structural features of the skull alone, properly to characterize the three species now assigned to *Gorgosaurus,* but in view of the great interval of time that has elapsed between Belly River and Lance, one appears justified in believing that it is too great a span in time for a species to pass unchanged from one to the other, and that with the discovery of additional materials characters will eventually be found that will adequately distinguish them.

The genus *Gorgosaurus* was established on an adequate specimen, consisting of the greater portion of an articulated skeleton, but the skull was badly crushed and broken with much of the top portion missing. Lambe (1917) described in detail such parts of the type skull as were available, and although today there are several well-preserved skulls of this genus known, a description of a complete cranium has not yet appeared. Because of this discrepancy in the literature the present specimen is here described in as much detail as its condition will permit.

DESCRIPTION

Parietal.—The combined parietals are relatively short and unite with the frontals by a nearly straight transverse suture. Their upper surfaces at the center rise into a thin, sharp-edged, antero-posterior sagittal crest and a transverse supraoccipital crest. The latter rises high above the level of the skull top. Its slightly thickened upper border, viewed from the rear, presents a sinuous outline divided at the center by the truncated end of the longitudinal crest. Whereas the sides of the supraoccipital crest converge slightly from top toward the bottom in *G. libratus,* as shown by the skull of A.M.N.H. No. 5434, there is a strong overhang of the upper half of the lateral border when viewed from the rear. At midheight the supraoccipital crest has a greatest transverse diameter of 116 mm.; at the bottom, which rests upon the exoccipital and paraoccipital bones, a long, tapering process extends outward to increase suddenly the transverse diameter to 144 mm. or more. This process is received in a slotlike depression of the squamosal at its junction with the paraoccipital. Above the top of the supraoccipital the parietal shows a triangular-shaped thickening that articulates directly with the heavy median part of the supraoccipital, probably functioning in the same capacity as the heavy, bluntly pointed posterior projection that stands out so prominently on the *Antrodemus* skull.

In front of the supratemporal crest the parietals are strongly contracted transversely between the supratemporal fossa, again widening at their anterior junction with the frontals, as shown in plate 2. Between the fossa they have a least diameter of 55 mm. The greatest length of the parietals at the center is 68 mm.

Frontal.—The frontal area in *Gorgosaurus lancensis,* owing to the coalescence of many of the sutural contacts, can be interpreted only somewhat uncertainly. The union with the parietal and postfrontal is quite clear, but the outline and anterior extent of the frontals where they meet the lacrimal and nasal bones cannot be surely determined. The median suture separating the paired frontals is clearly discernible on the anterior third of their length, but posteriorly the fusion is so complete as to leave no trace of the line of contact. On the right side, between the hornlike projections of the lacrimals, an offset in the bone surface extends backward and outward from the median suture, and is thought to represent the line of lateral union between the frontal, nasal, and prefrontal of that side. If this interpretation is correct, the combined frontals end anteriorly in a point deep within a V-shaped notch in the nasals as shown in plate 2. Contributory evidence as to the correctness of this interpretation is found in a skull of *Gorgosaurus libratus,* U.S.N.M. No. 12814, which shows a closely similar arrangement of these elements. That the frontal is coalesced with the prefrontal latterly appears to be indicated on the left side by a short sutural edge that extends inward and backward from the border of the orbital notch. If this is the posterior end of the prefrontal, it occupies a position similar to that of the prefrontal in *Antrodemus,* and quite unlike the more central position in the *Tyrannosaurus* skull. A wedge-shaped process of the frontal extends outward to fill the interspace between the postfrontal and prefrontal bones, but it appears to be excluded from participation in the orbital border by the articulation of these two elements at the bottom of the notch. On the right side of the skull there is no trace of the prefrontal suture.

The sagittal crest extends forward from the midline of the parietal on to the frontal, reaching its highest elevation on the posterior fourth of that bone. Anteriorly this crest drops rapidly downward to the level of the skull surface. It is estimated that the nasal bones at the center had a greatest length of about 112 mm.

Nasal.—The nasal bones, as in other members of the Deinodontidae, are especially long and narrow, with transversely rounded dorsal surfaces anteriorly, but flattening out on the posterior third. The central areas are coalesced into a single rugose element that is suturally separate anteriorly. The contact with the frontals is broad, not narrow as in *Tyrannosaurus;* the pointed ends of the combined frontals being received in a deep V-shaped notch on the midline, as shown in plate 2. Anteriorly the nasals have bifurcated ends, a heavy upper process that extends forward above the nares to meet an ascending process of the premaxillary which it underlaps, and a much weaker process that extends forward and downward along the upper surface of the maxillary border to meet an ascending process of the premaxillary and thus exclude the maxillary bone from participation in the boundary of the external nares. The lateral contacts of the nasal with the maxillary, lacrimal, and prefrontal bones have the sutures coalesced, and their course can be only approximately determined. A row of small foramina on the side of the left nasal, running posteriorly from the border of the nares, suggests that the roughened areas may have had a chitinous hornlike covering. The greatest length of the nasals is 388 mm.

Postorbital.—The bone here designated postorbital in all probability represents the coalesced postfrontal and postorbital. Since no trace of their sutural union can be detected in this specimen they are described as a single element. The postorbital is a triradiate bone with short, heavy inner-directed process that articulates with the frontal by a strong suture; a second slender, tapering process that extends backward and downward is received in a depressed groove on the outer side of the squamosal, thus forming the upper temporal bar; the third, the longer one of the three, also a tapering process, extends downward and laps along the anterior side of the jugal to form the wide bar separating the orbit and lateral temporal fossa. From the superior border to the end of the inferior branch it measures 114 mm. Its greatest antero-posterior diameter is 145 mm. There is no "postfrontal rugosity" as in *Tyrannosaurus* and the notch separating this bone from the lacrimal rugosity is shallow. At the bottom of this notch it appears to be in contact with the prefrontal, thus excluding the frontal from the orbital border.

Prefrontal.—The narrow area on the top of the skull, lateral to the frontal and wedged in between the lacrimal frontal and nasal bones, is here tentatively regarded as pertaining to the prefrontal (see pl. 2). If correctly determined, it has a greater dorsal exposure than in *Tyrannosaurus*, and it differs further in being in contact with the postfrontal.

Lacrimal.—The lacrimal of *Gorgosaurus lancensis* resembles those of *Antrodemus* and *Ceratosaurus* in having a stout, blunt-edged elevation rising from its outer superior surface. It may have supported, as first suggested by Osborn (1903), "something in the nature of a low dermal horn." A similar horn-projection is present on the skulls of *G. libratus* and *G. sternbergi*, but is absent in *Tyrannosaurus rex*. On the external side the base of this "hornlike" projection is excavated, and the bone is still further lightened by internal cavities, as shown by the incomplete right element which lacks its top (see pl. 2).

The sutural contacts of the lacrimal with the adjacent, prefrontal (?), frontal, and maxillary bones cannot be accurately traced in this specimen. Posteriorly it is separated from the postorbital by a narrow notch. Ventrally it unites with the jugal, the posterior angle being received in a notch in the top of that bone, but anteriorly these two bones appear to lap one another.

Premaxillary.—The premaxillary, as in other deinodonts, is reduced in size. It carries either four or five teeth, a point that cannot be certainly determined by this specimen owing to the obliteration of the premaxillo-maxillary suture. In all probability it will be found there are four premaxillary teeth as in *Gorgosaurus libratus,* so clearly demonstrated by Lambe (1917). The slender superior process rising from the upper anterior border, with its counterpart of the opposite side, meets the nasals above the midlength of the external nares.

Maxillary.—Roughly triangular in outline, the maxillary is deeply excavated posteriorly by the large antiorbital fenestra. The posterior process that extends backward to meet the jugal is especially long and slender, its tapering termination ending below the center of the orbital opening as it does in *G. sternbergi.* Above, it unites with the nasal and lacrimal, but in this specimen most of the sutural contacts are obscured by the coalescence of the bones, as is the union with the premaxillary. On the left side of the mid-lateral surface of the maxilla adjacent to the position of the pre-maxillo-maxillary suture there is evidence of a small opening, which in *Tyrannosaurus* Osborn designates the third antiorbital fenestra. It appears to be absent on the right side of this specimen. The maxillary is excluded from participation in the boundary of the nares by a slender downwardly directed process of the nasal.

The base of the ascending maxillary process is perforated by the small second antiorbital fenestra. The surface of the bone in front of this fenestra is smooth and depressed, forming a marginal tract at a lower level than the general surface of the skull at this point. Viewed from the side the dental border is sinuous, with a row of dental foramina. The greatest length of the maxillary is about 405 mm., of which 280 mm. is tooth bearing. There are clearly 13 teeth and possibly 1 more if the premaxillo-maxillary suture cuts between the first and second U-shaped teeth of the front series as Lambe (1917) found it to do in the type of *G. libratus.* This point cannot be determined in this specimen owing to the coalescence of this suture.

Jugal.—The jugal has the usual triradiate shape, but is more slender and elongate antero-posteriorly than in *Tyrannosaurus.* It extends forward as a tapering process to join the maxillary by squamous union. It is underlapped for nearly half its length by the slender posterior process of the maxilla that terminates below the center of the orbit. This anterior process of the jugal is perforated by a large oval-shaped jugal fenestra, ventral to its union with the lacrimal. There is a notch in the upper border of the jugal for the reception of the lower posterior end of the lacrimal, but anterior to this notch it overlaps the side of the descending lacrimal. The tapering superior process unites by squamous union with the descending process of the postorbital, the two forming the postorbital bar which separates the orbit and the lateral temporal fenestra. Posteriorly the jugal is overlapped by a fingerlike process from the quadratojugal, as shown in plate 1. In this specimen crushing has broken this process in two so that its full posterior extent is not to be observed (see pl. 1). The lower border, anterior to the forward termination of the quadratojugal, has a flattened projection that extends prominently downward as a blunt process (see pl. 1). That this is a normal development is demonstrated by its presence on the opposite side. This process appears to be absent in *G. sternbergi* but is present in *G. libratus*. The jugal forms all of the lower boundary of the orbit and little, if any, of the postero-ventral boundary of the large antiorbital fenestra. The greatest height of the jugal is 170 mm.

Squamosal.—The right squamosal is missing but the left is almost complete, and the open sutures give a clear picture of its extent and relationship to the surrounding elements (see pls. 2 and 3). Externally the forwardly directed bar is overlapped on the outside by the posterior process of the postorbital, the two forming the upper supratemporal bar; an inwardly directed process passes in front of the high vertical supraoccipital crest to lap along the parietal on the postero-medial side of the supratemporal fossa; posteriorly the squamosal rests against the front of the paraoccipital process; on the external ventral side a slender process curves forward and downward to cap the top of the quadratojugal. Ventrally it articulates with the quadrate, but this side is hidden by enveloping matrix.

Quadratojugal.—The lateral view of the skull (see pl. 1) shows clearly how the quadratojugal and quadrate bones have been crushed forward, thus closing the lower part of the lateral temporal fenestra to a narrow slotlike opening. As shown by the overlapping broken ends of the lower anterior process, this fossa should be at the least 26 mm. wider at the bottom than as shown in plate 1. The anterior border of the quadratojugal within the fossa is incomplete, so that its full extent and proper outline cannot be determined. Immediately below midlength, on the outer side, the surface is indented by a shallow rounded depression. Internally it unites by suture with the quadrate except at the point of the large quadrate foramen. The proximal end is capped by a descending process of the squamosal. The greatest length of the inferior border is estimated to be about 95 mm.; the greatest height 110 mm. The sutures on the inner side with the quadrate are coalesced and cannot be traced.

Quadrate.—Both quadrate bones are so much hidden by matrix, or closely enveloped by the squamosal above and the mandible below, that little is to be seen of these elements except from the rear. The large vertical ovate quadrate foramen lies between the quadratojugal externally and the quadrate internally. Below this foramen the distal portion of the quadrate rapidly widens toward the outside where it is coalesced with the quadratojugal. The left quadrate at the distal end has a greatest transverse diameter of 67 mm. The bilobed distal extremity fits closely into the cotyloid depression of the mandible. On the inner side slightly above the distal end a process extending inward and forward articulates with the pterygoid, but its full forward development is hidden in the adhering matrix.

Occipital region.—The coalescence of most of the bones of the occipital region of the present skull makes a detailed study of its several elements very unsatisfactory. Viewed from the rear the median upper part of the occiput is dominated by the vertically and horizontally expanded supraoccipital crest formed wholly by the parietal. Medially it envelopes the stout supraoccipital; its lower outer border is continued outward as a slender, pointed process that rests on the upper border of the paraoccipital process in a transverse depression crossing the back of the squamosal.

The upper end of the supraoccipital is squarely truncate, with its surface rugosely roughened. This surface, in conjunction with the lateral pits, probably gave attachment for the *ligamentum nuchae*. Laterally and ventrally its sutural limits cannot be traced. For that reason it is not known whether the supraoccipital participated in the boundary of the foramen magnum or not.

The exoccipitals contribute extensively to the formation of the occipital condyle as in *Antrodemus valens*. Their dorsal connection with the supraoccipital can no longer be traced. The surfaces lateral to the foramen magnum are perforated by two foramina, the larger and most posterior one being for the passage of the twelfth or hypoglossal nerve; the smaller and more anterior one for the eleventh or accessory nerve.

The paraoccipitals or opisthotics coalesce toward the median line with the exoccipitals and below the latter turn downward to join the basioccipital by an oblique suture. Both paraoccipital processes lack their outer ends, though the left element is sufficiently complete to show it was expanded and in contact with the posterior surface of the squamosal.

The basioccipital contribution to the occipital condyle looks strongly downward. This articular surface, when viewed from below, is subtriangular in outline as contrasted with the oval shape in *Tyranno-*

saurus. The condyle, as in nearly all Dinosauria, is inclined ventrally in relation to the longer horizontal axis of the skull.

Anteriorly, where the basioccipital meets the broad basisphenoid, strong, diverging basioccipital processes extend forward and downward to a point 44 mm. below the level of the occipital condyle. Laterally, they articulate with the exoccipitals and anteriorly with the basisphenoid. The median area between the descending processes is shallowly concave transversely. In this specimen this whole region has been considerably flattened by vertical crushing.

The basisphenoid viewed from below is subrectangular in outline with the greatest diameter transverse. Posteriorly it unites with the basioccipital, anteriorly with the pterygoids. The smooth surfaces of the enlarged basisphenoid processes that articulate with the pterygoids indicate this joint to have been movable. These processes are joined transversely by a wide septum of bone as in *Tyrannosaurus*. The posterior surface of the basisphenoid is hollowed out with a single opening near the center that leads upward and backward toward the brain cavity. This is identified as the internal carotid foramen. A second opening posterior to the carotid foramen has every appearance of being abnormal; it is asymmetrically placed and the adjacent surfaces suggest an unhealthy condition of the bone. The sides of the basisphenoid are hidden in the enveloping matrix.

Palate.—Although the type skull has much of the palate present, postmortem crushing, coalescence of the sutures, and adhering matrix have made it impossible at this time to give a complete account of the structural details of this important part of the cranium.

The palate shown in plate 3 is an attempt to give the ventral view of the pterygoids in combination with the palatines, which in this skull are visible only in the antiorbital fenestra and from the dorsal side. Since there is ample opportunity here for a difference of opinion as to their proper interpretation, this view should be used with caution.

The pterygoids, as in *Tyrannosaurus*, unite with the basipterygoid processes by movable joints. They unite laterally with the ectopterygoids and near the posterior end a process extends upward, outward, and backward to meet the quadrate, but the full extent of this sutural contact is partly hidden in the matrix. The broad outward extension of the pterygoid that meets the ectopterygoids in relative extent and outline closely resembles those of *Tyrannosaurus* as illustrated by Osborn (1912, fig. 5). How much of this winglike expansion is ectopterygoid cannot be determined because of the coalescence of the sutures. The ectopterygoid portion appears to be perforated by an ovate opening as in *Tyrannosauras*. The internal barlike parts of the pterygoids extend forward with their inner borders parallel, and with their widest surfaces strongly inclined upward from the horizontal, indicating a high but narrow palatal roof. They do not meet on the median line. This bar portion gradually widens toward the front, its anterior end is bifurcated. The outer or heaviest branch meets the palatine by a straight transverse suture; the inner branch, a slender, flattened extension of the median side, turns gradually inward to abut the inward extension of the palatine, thus inclosing a subtriangular vacuity between the two bones at this point. In *Tyrannosaurus* the vacuity is absent, the slender inner process extending forward tight along the median site of the palatine to meet the vomer. The vomer in *G. lancensis* has been tentatively identified as extending forward from the palatine to disappear in the matrix between the closely appressed jaws (see *v*, pl. 1).

Mention should be made of the doubtful nature of the exact point of sutural union between the pterygoid and palatine. This suture as tentatively determined is based on the presence on the ventral or palatal surface of a coalesced suture. This determination, however, needs additional confirmation. As preserved the main portions of the palatine bones have been crushed upward to a nearly perpendicular position, as best shown in the left antiorbital fenestra (see *p*, pl. 1). The right palatine occupies a similar position in the opposite fenestra but it is less well preserved. A skull of *G. libratus*, U.S.N.M. No. 12814, shows a similar position of the left palatine.

The outer end of the palatine that articulates with the maxillary is extended forward as a slender tapering process, and posteriorly a much shorter process contacts the jugal and possibly the lacrimal. The heavy central portion of the palatine, shown best in the left antiorbital fenestra (pl. 1), stands nearly vertical. Although it is quite evident that in their normal relationships the palatines would meet on the medial line of the palate, it is also clear they must have been steeply inclined upward toward the center of the palate; otherwise, their great length would cause them to overlap strongly if brought to a horizontal position. On the dorsal surface close to the palatine-maxillary suture the palatine is perforated by two small ovate openings, the smaller one being anterior. In *Tyrannosaurus* Osborn (1912) shows only one opening through the palatine. The inner end of the palatine is extended forward as a relatively wide tapering process that disappears from view in the matrix now filling the skull anterior to the large antiorbital fenestra. The anterior portion of this process may represent the posterior end of the vomer, as shown in plate 1. This suggestion is made on the basis of the presence of a diagonal break crossing this process in practically the same manner on both sides of the palate.

If the conclusion reached here is correct, the internal narial opening is bounded principally by the palatine, only slightly by the maxillary and vomer, and the vomers would be excluded from contact with the pterygoids as they are in *Platecarpus* and *Cyclura*. Until confirmatory evidence is available, however, the suggestions made should be used with caution for it would seem highly improbable that the palate of *Gorgosaurus* would differ so radically from that of *Tyrannosaurus* and *Ceratosaurus*, both of which have the pterygoids and vomers articulating on the median line.

EXTERNAL OPENINGS IN THE SKULL

Besides the orbital and narial openings there are four other fenestra on the side of the skull. The *orbit* is subround, having a greatest vertical diameter of 122 mm., a greatest antero-posterior diameter of 95 mm. Dorsally the upper boundary is formed by the lacrimal prefrontal and postfrontal. The frontal does not appear to participate in its boundary. Anteriorly the lacrimal forms the whole border; ventrally it is bounded by the jugal, and posteriorly by the postorbital.

The *first antiorbital fenestra* is the largest opening in the skull, measuring 153 mm. antero-posteriorly, with a greatest diameter dorsoventrally of 111 mm. Its upper boundary is formed by the lacrimal and maxillary, anteriorly by the maxillary, and ventrally by the maxillary, lacrimal, and jugal. The small *second antiorbital fenestra* lies wholly in the maxillary bone. The *external nares* are elongate oval in outline, and have a greatest antero-posterior diameter of 83 mm., a vertical diameter of 32 mm. The boundaries are about equally divided between the premaxillary and nasal bones; the maxillary does not participate.

The *latero-temporal fossa* is much narrowed by the pushing forward of the quadrate and quadratojugal bones, so that a true conception of its proper outline is not to be obtained from this specimen. Above it is bounded by the posttemporal bar formed by the united processes of the squamosal and postorbital bones; anteriorly by the jugal and descending process of the postorbital; ventrally by the quadratojugal, and posteriorly by the quadratojugal and squamosal. The greatest vertical extent of this opening is about 152 mm.

The jugal foramen is an ovate opening that perforates the jugal immediately below its junction with the lacrimal. Its antero-posterior diameter measures 29 mm.

The supratemporal fossa is bounded anteriorly by the parietal and postfrontal + postorbital; externally by the postorbital and squamosal; posteriorly by the squamosal and internally by the parietal and squamosal.

The quadrate foramen lies between the quadrate and quadratojugal and looks directly backward. Its longest diameter dorso-ventrally measures 44 mm. in length and 18 mm. wide at the center.

Mandible.—Although the lower jaws are completely preserved, they are so closely articulated with the skull that much of their detailed structure is hidden from view. In so far as comparison can be made, except for their smaller size, the jaws are in close agreement with those of *Gorgosaurus libratus.*

Viewed from below the anterior ends of the rami are in close apposition, having a combined width of 55 mm. In a posterior direction they rapidly diverge (see pl. 3), until across their posterior ends they have a spread of 330 mm. from side to side.

The dentary, as in other deinodonts, has a receding anterior end as contrasted with the more squarely truncate ends of the megalosaurians *Ceratosaurus* and *Antrodemus.* Posteriorly the dentary articulates above with the large surangular and below with the angular, underlapping the one and overlapping the other. In front the ventral border of the dentary is heavy and rounded, gradually narrowing transversely toward its posterior extremity which laps along the outer side of the angular as a thin fingerlike extension. The inside of the posterior part of the dentary is hidden from view by the overlying splenial.

The surangular in *Gorgosaurus* has been so completely described by Lambe (1917, pp. 13 to 16) that it seems unnecessary to repeat the description here.

The angular is clearly defined on both rami, and is almost wholly confined to the outer aspect of the ramus, being slightly visible on the inner side near its anterior end where it underlaps the prearticular and the posterior extremity of the splenial. In outline it is roughly triangular in shape, overlapping the surangular above and extending posteriorly to a sharp point that is separated internally and posteriorly from the prearticular by the interposition of a long tapering process that extends forward from the articular. Anterior to this process it comes in direct contact with the prearticular. On the anterior end it sends forward a small fingerlike process that is received between the splenial and dentary on the ventral surface. On the lateral surface at the point of junction with the dentary and surangular, there is a small elongate foramen that leads forward to the inside of the dentary. This foramen in position corresponds to the large oval opening in the

Ceratosaurus ramus. The left angular has a greatest length of 174 mm., a greatest width of 52 mm.

The coronoid, as in *Tyrannosaurus,* is a small, thin bone that is confined to the forward part of the pterygoid fossa wedged in between the prearticular and surangular bones, and only visible on the inside of the ramus.

TABLE 1.—*Comparative measurements of skulls*

	Gorgosaurus lancensis C.M.N.H. No. 7541 Type	*Gorgosaurus sternbergi* A.M.N.H. No. 5664 Type	*Gorgosaurus libratus* G.S.C. No. 2120 Type	*Gorgosaurus libratus* A.M.N.H. No. 5336	*Tyrannosaurus rex* A.M.N.H.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*
Length of skull, pmx. to mand. condyle..	570	678	...	980	1355
Length of skull, pmx. to occipital condyle	572	...	...	925	1210
Height of skull, supraoc. crest to mand. condyle	190	205	...	393	635
Width of skull across quadratojugals...	...	...	...	380	835
Length of upper dentition..............	300	340	...	495	...
Length of lower jaw..................	570	690	950	999E	1205
Height of muzzle above last tooth......	171	160	...	260	...

The prearticular is a long curved element that extends anteriorly from the articular and, with the angular, contributes to the formation of the lower posterior mandibular border. At midlength it curves strongly upward, terminating in a pointed end that is wedged in between the upper posterior end of the splenial and the surangular. This half of the bone is relatively thin transversely; narrowest at the center, it gradually widens toward both ends. It is almost identical in shape with the prearticular of *Tyrannosaurus* as figured by Osborn (1912, fig. 18), but in *Gorgosaurus lancensis* the contact with the surangular is much stronger. The prearticular-articular contact at the posterior end is partly coalesced, but on the external side of this end where the tapering process separates it from the surangular the suture on both jaws is to be clearly observed.

The articular forms the posterior portion of the ramus, but owing to the coalescence of most of the sutures and the covering of the superior surfaces by the closely articulated quadrate, the articular bones in this specimen cannot be delimited. Internally, it develops a wide flattened process that extends inward at nearly right angles to the length of the ramus. Ventrally a long tapering process extends forward between the posterior ends of the prearticular and angular, a condition previously noted in *Albertosaurus* by Lambe (1904, pl. 1).

Measured from the inner end of the articular process to the outside of the ramus, this posterior end of the jaw has a greatest diameter of 115 mm.

Hyoid.—Embedded in the matrix covering the midpalatal region a slender, subround, sinuous bone, with slightly enlarged ends, is identified as one of the hyoid elements. From end to end in a straight line it has a length of about 234 mm., greatest diameter of the posterior end, 13.5 mm. Its position as found *in situ* is shown in plate 3, *h*.

Dentition.—The upper dentition of *Gorgosaurus lancensis* consists of 37 teeth, of which the crowns of more than half are present in the type specimen, 13 on the left and 14 on the right. Owing to the coalescence of the premaxilla-maxillary suture, the number of teeth carried by each of these bones cannot be positively determined. In the front of the series there are 10 teeth of reduced size, rodlike and with flattened sides. As far as these teeth can be examined, they appear to be in full accord with those described by Leidy (1868) under the genus name *Aublysodon*. On similarity of structure alone all these teeth might be regarded as premaxillary, but Lambe (1917, p. 16) has pointed out that "one of the principal distinctive characters of the dentition of *Gorgosaurus* is the similarity of the first maxillary tooth in size and shape to those of the premaxilla." If the same condition prevails in the specimen under consideration, there are 4 premaxillary and 14 maxillary in this species, the same as in *G. libratus*.

The maxillary teeth are of the usual compressed trenchant type, irregular in size, with serrated edges and backward curvature near the pointed end. The irregularities in size of adjoining teeth in the maxillary series are due to the different degrees of extrusion, and they are not always in agreement on the two sides of the skull. On the left side the third, fifth, seventh, and eleventh are larger than those fore and aft, whereas on the right side the third, sixth, eighth, and tenth are the largest teeth. On this side there is a gradual decrease in size from the tenth backward. The fourteenth tooth is especially small.

The teeth of the lower jaw are completely hidden by the skull, so complete is their articulation.

The dental formula of 18 upper teeth on a side is in full accord with the type of *Gorgosaurus libratus* as distinguishing it from *Tyrannosaurus* with 16 upper, *Albertosaurus* with 15, and *Dromaeosaurus* with 12.

At this time it does not appear possible to determine genera of the Deinodontidae by detached and scattered teeth.

TABLE 2.—*Dentitions of Deinodontidae compared*

	Maxillary	Premaxillary	Lower jaw
Gorgosaurus lancensis	14	4	..
G. libratus	13	4	14
G. sternbergi	15?	?	..
Tyrannosaurus rex	12	4	13 to 14
Albertosaurus sarcophagus	12	..	14 to 15

DISCUSSION OF UPPER CRETACEOUS DEINODONTS

Arranged in chronological order the following genera and species of deinodont dinosaurs have been named as occurring in the Lance formation of North America: *Aublysodon amplus* Marsh, 1892; *A. cristatus* Marsh, 1892; *Manospondylus gigas* Cope, 1892; *Tyrannosaurus rex* Osborn, 1905; and *Dynamosaurus imperiosus* Osborn, 1902.

The two species of *Aublysodon* named by Marsh were each based on a single anterior tooth, and on the assumption that the types were inadequate Matthew and Brown (1922) referred both to "? *Tyrannosaurus* sp." At this same time these authorities pointed out that the genus *Aublysodon* had to be abandoned on the ground of priority as being a synonym of *Deinodon*.

Manospondylus gigas Cope, based on two worn vertebral centra, is regarded indeterminate by Osborn (1916), a decision concurred in by Matthew and Brown (1922). *Tyrannosaurus rex* is a thoroughly good genus and species, based on an adequate specimen. *Dynamosaurus imperiosus* was abandoned by Osborn as a synonym of *Tyrannosaurus rex*. This brief review of the named deinodonts from the Lance shows that *Tyrannosaurus rex* is the only one of the five named species that has a clear title.

On geological position alone it would be to the Edmonton *Albertosaurus* that one would first turn in looking for the progenitor of the Lance *Gorgosaurus lancensis,* but here again adequate comparison cannot be made owing to the fragmentary nature of the only known skulls of *A. sarcophagus*. The genus *Albertosaurus* has not been satisfactorily characterized, and Matthew and Brown (1922, p. 374) have already suggested that it may be identical with *Deinodon*. Mention should also be made of *A. arctunguis* Parks (1928), a species based on a partial skeleton without skull. Parks distinguished it from *A. sarcophagus* on differences found in the pes and pelvic bones, but since there is the possibility of wrong association of these parts of the original Osborn types, this species at the present time is also of uncertain value.

In the Belly River formation the genus *Gorgosaurus* is the single known representative of the Deinodontidae. Although *G. libratus* and

G. sternbergi are both established on articulated skeletons, Matthew and Brown (1922, p. 383) have pointed out there is nothing in the dentition to separate *Gorgosaurus* from *Deïnodon* and that, as far as the teeth are concerned, they would seem to be the same genus. For the present, however, I fully concur with their final recommendation that "pending discovery of adequate topotypes in the Judith River beds the identity has not been finally and conclusively proven. There may be differences in the skull." Although not prepared at this time to recommend the abandonment of *Deinodon* as an indeterminate genus, accumulating evidence offers little hope of its eventual stabilization. Thus, in the present paper, both *Deinodon* and *Gorgosaurus* are regarded as valid genera.

In the eastern United States the deinodonts are represented by *Dryptosaurus aquilunguis* from the Upper Greensand of New Jersey, and two doubtfully referred species, *D. medius* and *D. potens,* from the Arundel of Maryland and the District of Columbia, respectively. Originally described as *Laelaps* by Cope (1866), Marsh (1877) found it to be preoccupied and proposed the name *Dryptosaurus* to replace it. In 1890 this same authority proposed and characterized the family Dryptosauridae. Should the genus *Deinodon* eventually be abandoned, thus rendering the family name Deinodontidae untenable, the New Jersey family name is available to replace it.

This brief review of the large Upper Cretaceous carnivorous Dinosauria focuses attention on the very unsatisfactory state of our knowledge concerning the nomenclatural status of many of the included forms, and the great need for the recovery of topotypic materials if the family is ever to be placed on a solid foundation.

The geologic distribution of the Deinodontidae as known at the present time is graphically shown in the accompanying table.

TABLE 3.—*Geologic distribution of the Deinodontidae*

Formation	Western Upper Cretaceous
Lance	*Tyrannosaurus rex* Osborn
	Gorgosaurus lancensis Gilmore
Edmonton	*Albertosaurus sarcophagus* (Cope)
	A. arctunguis Parks
Belly River and Judith River	*Gorgosaurus libratus* Lambe *G. sternbergi* Matthew and Brown
	Deinodon horridus Leidy
	Eastern Upper Cretaceous
Hornerstown	*Dryptosaurus aquilunguis* (Cope)
Arundel	*D. ? medius* (Marsh) *D. ? potens* (Lull)

REFERENCES

Brown, Barnum.

1907. The Hell Creek beds of the Upper Cretaceous of Montana. Bull. Amer. Mus. Nat. Hist., vol. 23, pp. 823-845.

Cope, E. D.

1866. Remarks on dinosaur remains from New Jersey. Proc. Acad. Nat. Sci. Philadelphia, June, pp. 275-279.

Gilmore, Charles W.

1920. Osteology of the carnivorous Dinosauria in the United States National Museum, with special reference to the genera *Antrodemus* (*Allosaurus*) and *Ceratosaurus*. U. S. Nat. Mus. Bull. 110, pp. 1-155, 36 pls., 143 text figs.

Hay, O. P.

1908. On certain genera and species of carnivorous dinosaurs, with special reference to *Ceratosaurus nasicornis* Marsh. Proc. U. S. Nat. Mus., vol. 35, pp. 351-366, text figs. 1-4.

Lambe, Lawrence M.

1904. On *Dryptosaurus incrassatus* (Cope) from the Edmonton series of the Northwest Territories. Contr. Can. Paleont. Geol. Surv. Canada, vol. 3, pt. 3, pp. 5-25, pl. 8.

1917. The Cretaceous theropodous dinosaur *Gorgosaurus*. Geol. Surv. Canada, Mem. 100, No. 83, Geol. Ser., pp. 1-80, text figs. 1-84.

Leidy, J.

1856. Notice of remains of extinct reptiles and fishes, discovered by Dr. F. V. Hayden in the Bad Lands of the Judith River, Nebraska Territory. Proc. Acad. Nat. Sci. Philadelphia, vol. 8, pp. 72-73.

Marsh, O. C.

1877. Notice of a new and gigantic dinosaur. Amer. Journ. Sci. (3), vol. 14, pp. 87-88.

1892. Notes on Mesozoic vertebrate fossils. Amer. Journ. Sci., vol. 44, pp. 174, 175, pl. 3, figs. 4-6.

Matthew, W. D.

1920. Canadian dinosaurs. Nat. Hist., vol. 20, No. 5, pp. 541, 544.

Matthew, W. D., and Brown, Barnum.

1922. The family Deinodontidae, with notice of a new genus from the Cretaceous of Alberta. Bull. Amer. Mus. Nat. Hist., vol. 46, art. 6, pp. 367-385, fig. 1.

1923. Preliminary notices of skeletons and skulls of Deinodontidae from the Cretaceous of Alberta. Amer. Mus. Nov., No. 89, pp. 1-10, figs. 1-5.

Osborn, H. F.

1903. The skull of *Creosaurus*. Bull. Amer. Mus. Nat. Hist., vol. 19, art. 31, pp. 697-701.

1905. *Tyrannosaurus* and other Cretaceous carnivorous dinosaurs. Bull. Amer. Mus. Nat. Hist., vol. 21, art. 14, pp. 259-265.

1912. Crania of *Tyrannosaurus* and *Allosaurus*. Mem. Amer. Mus. Nat. Hist., vol. 1, pt. 1, pp. 3-30, pls. 1-4.

1916. Skeletal adaptations of *Ornitholestes, Struthiomimus, Tyrannosaurus*. Bull. Amer. Mus. Nat. Hist., vol. 35, pp. 733-771, 3 pls., 21 figs.

PARKS, W. A.
1928. *Albertosaurus arctunguis*, a new species of theropodous dinosaur from the Edmonton Formation of Alberta. Univ. Toronto Stud., Geol. Ser., No. 25, pp. 1-42, pl. 1.

EXPLANATION OF PLATES

PLATE 1

Skull and jaws of *Gorgosaurus lancensis* viewed from the left side. Type. C.M.N.H. No. 7541. *p*, palatine; *v*, vomer. About ¼ natural size.

PLATE 2

Skull of *Gorgosaurus lancensis* viewed from above. Type. C.M.N.H. No. 7541. About ¼ natural size.

PLATE 3

Skull and jaws of *Gorgosaurus lancensis*. Palatal view. Type. C.M.N.H. No. 7541. *h*, hyoid. About ¼ natural size.

PLATE 4

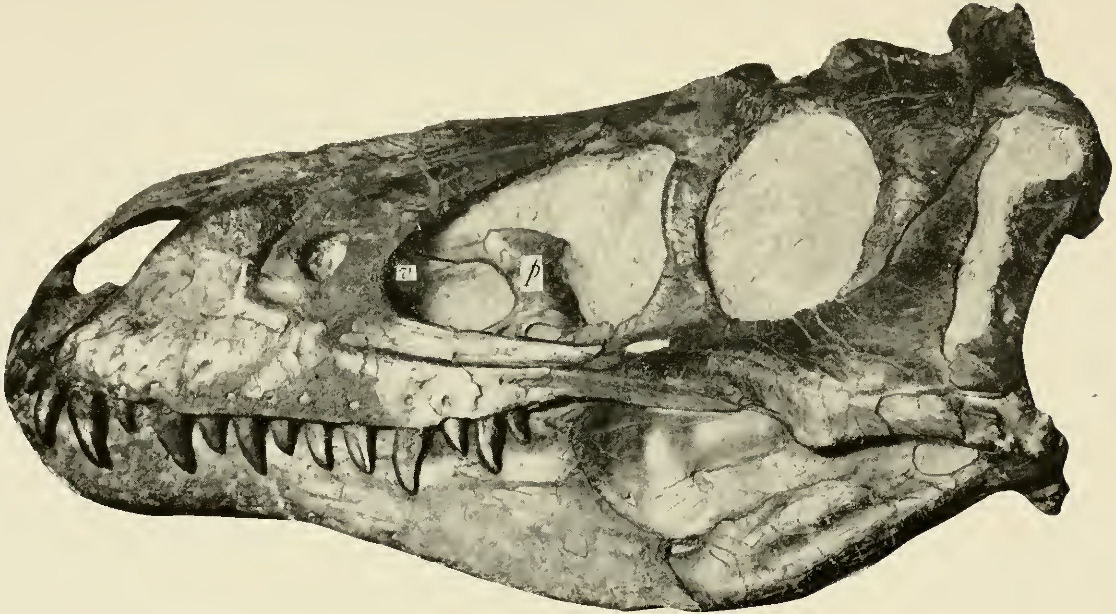
Comparison of *Gorgosaurus* skulls

FIG. 1. Skull and jaws of *Gorgosaurus lancensis*. Type. C.M.N.H. No. 7541. Viewed from left side (reversed).

FIG. 2. Skull and jaws of *Gorgosaurus sternbergi*. Type. A.M.N.H. No. 5664. Viewed from the left side.

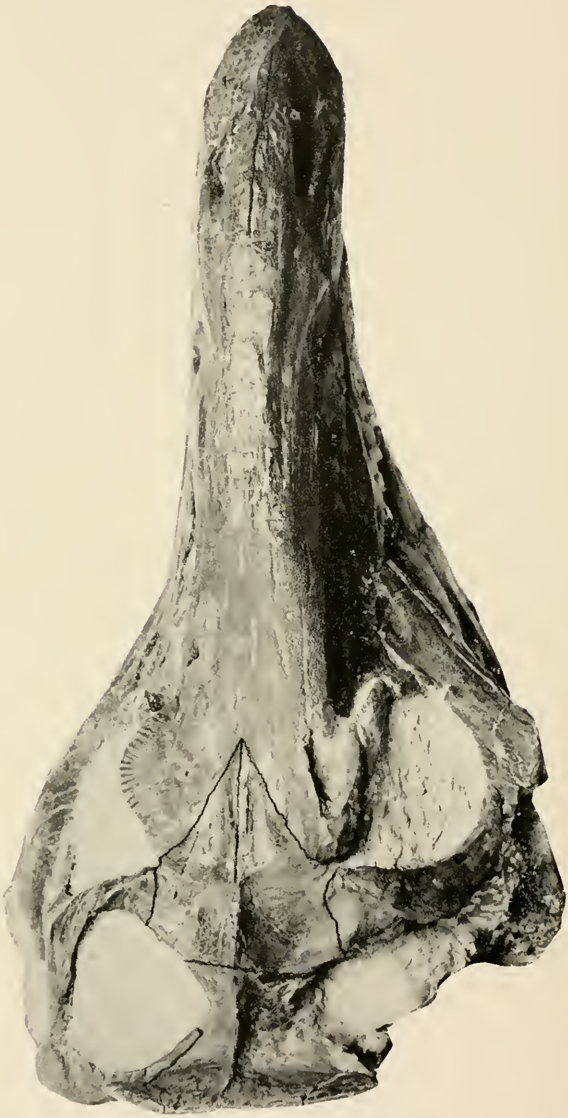
FIG. 3. Skull and jaws of *Gorgosaurus libratus*. A.M.N.H. No. 5434. Viewed from left side.

All figures about 1/10 natural size.



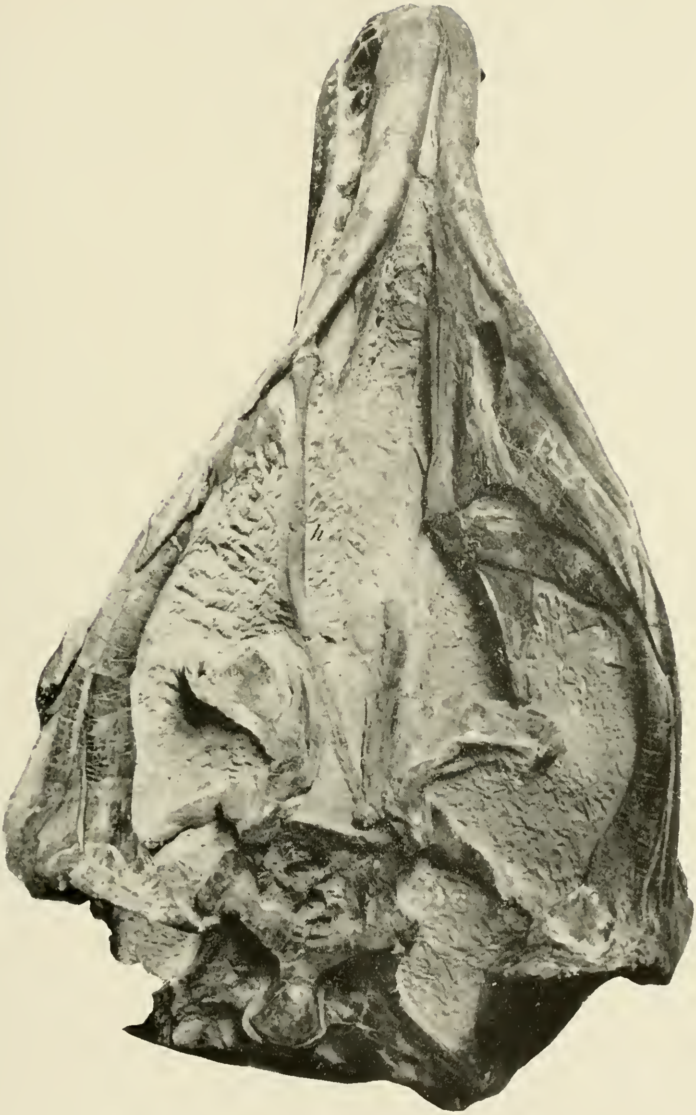
GORGOSAURUS LANCENSIS

(For explanation, see p. 19.)



GORGOSAURUS LANCENSIS

(For explanation, see p. 19.)



GORGOSAURUS LANCENSIS

(For explanation, see p. 19.)

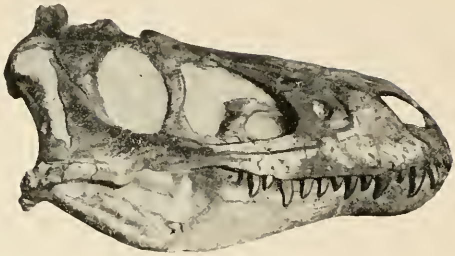


Fig. 1

Fig. 2

Fig. 3

COMPARISON OF GORGOSAURUS SKULLS

(For explanation, see p. 19.)