Acrocanthosaurus atokensis, a New Genus and Species of Lower Cretaceous Theropoda From Oklahoma

J. Willis Stovall and Wann Langston, Jr.*

Museum of the University of Oklahoma;
School of Geology, University of Oklahoma, Norman

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Abstract

A new genus and species of aberrant Theropoda based on remains of two individuals from the Trinity sands of southeastern Oklahoma is described. All important parts of the skeletons are represented and indicate an animal of exceptional size. The genus is characterized by greatly elongated and massive neural spines in allusion to which the generic name *Acrocanthosaurus* is proposed. In general, the skeletal features indicate a large rather advanced carnosaur, which, however, had not yet reached the high degree of development present in the Upper Cretaceous deinodonts. The relationships to other long-spined forms are discussed. Despite marked similarities to certain members of the Megalosauridae, the present genus appears most closely allied to the Allosauridae.

The status of *Altispinax* is discussed.

* Now of Museum of Paleontology, University of California, Berkeley.

INTRODUCTION

In the Spring of 1940, reports of the presence of numerous large bones in Atoka County, Oklahoma, were received by the senior author. In April of that year, the writers, in company with Dr. C. N. Gould, former director of the Oklahoma Geological Survey, visited the location and found a considerable part of the skeleton of a large Trinity carnivorous dinosaur. The bones were on the farm of Mr. Herman Arnold in the southeast part of the southwest quarter of Section 26, Township 4 South, Range 14 East.

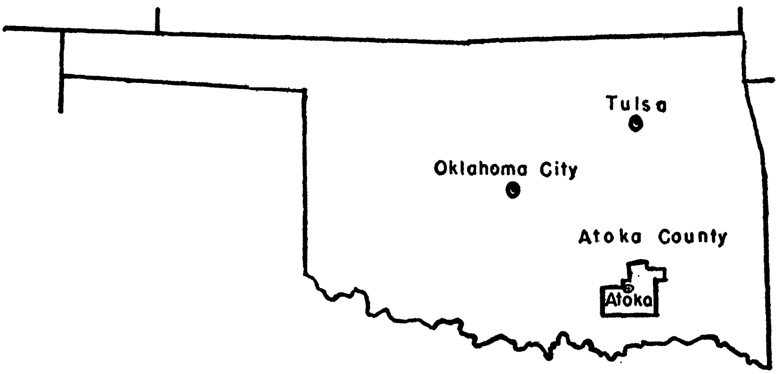

Fig. 1.—Index map of Oklahoma showing the area with which this paper is concerned.

Excavation was made by a Works Progress Administration crew under the direction of the senior author. Further exploration was carried on by the crew and a second skeleton was found on the section line three quarters of a mile east on the land of Mr. W. P. Cochran. It is with this and the specimen from the Arnold farm that this paper is concerned.

Exploration was continued intermittently during the excavation period of 1940 and 1941. In that time, partial dinosaur skeletons were found at nine other places in this township.

Owing to the difficulties of carrying on field work during World War II and because the junior author was serving in the Navy, the project was discontinued until his return to the University in 1945.

While these are not the first dinosaur remains found in the area, they are the most important. Pierce Larkin (1910) described a coracoid of a large sauropod from the Trinity (Lower Cretaceous). The bone was found about 25 miles almost due west of the location of the type. Since that time, but prior to the present discoveries, no vertebrate remains have been reported from the Lower Cretaceous deposits of the area. However, several subsequent discoveries of dinosaurian remains have been made in beds of Trinity age in Texas, but none have as yet been described.

The area is a difficult one to work because of the scarcity of passable roads and its forested condition. Culture and drainage maps of 27 of the 36 sections were prepared, section by section.

Many authors have observed that the Trinity overlaps, unconformably, the Pennsylvanian beds and is conformably overlain by the Goodland limestone. The Trinity is generally described as a beach or near-shore deposit, probably in part because of the presence of a conglomerate that may be of beach origin and is said to form a basal member. The senior author is of the opinion that much more study will be necessary before the question of the origin of the Trinity can be answered. There are several factors that are as favorable to a hinterland as to an off-shore origin for the sands of this group. The conglomerate that occurs at the base is more discontinuous than one would expect to find if it were a beach deposit. There are many lenses of blue or red clay, many fragments of fossilized wood, cycads and dinosaur bones, although the presence of interbedded limestones containing Lower Cretaceous marine fossils clearly indicate that the group was put down at or near the critical level of Lower Cretaecous seas.

Further south, the Trinity consists of the Travis Peak, Glen Rose and Pulaxy which, however, have not been identified in Oklahoma. The group dips at about 60 feet per mile and is about 500 feet thick, and the fossils in Section 26 were found about 120 feet below the top.

In this region, the Trinity can be distinguished from Quaternary stream deposits of sand with difficulty although it is generally more compact than the latter, has a more characteristic yellow cast and is more continuous. Toward the west and south, the Trinity becomes more white and on the Red River is a pure white sand. Resting on the surface, there are pebbles and a few cobbles of quartz and quartzite. Associated with the bones on the Cochran farm, there were pebbles of red and brown chert which may or may not be indigenous to the group. Taff (1902) believed that the "Quartz pebbles are foreign to the region, while the chert is local, being derived from the Talihini chert, near which it is most abundant in the vicinity of Black Knob Ridge." It is possible that the basal conglomerate of the Trinity was derived largely from the Talihini (Silurian) and that the surface pebbles are derived in turn from the basal conglomerate having been washed down slope by local streams. Some of the pebbles are polished and in that respect are suggestive of the so-called gastroliths of the Cloverly formation. One specimen (not described in this paper) was a nearly perfect skull of a dinosaur almost identical with one collected by the writers from the Cloverly formation on the Crow Agency, Montana. The Lower Cretaceous age of the Cloverly is thus confirmed. Authors assign the Trinity approximately to Petapsco time in Maryland and Delaware and the Upper Aptian and Lower Albian of Europe.

Neither skeleton described in this paper is complete, but there is little duplication of the individual elements. Where repetition does occur, however, the similarity between the individuals is striking. With the exception of the smaller size of the second specimen, which was probably a younger animal, no noteworthy differences between the two are apparent.

The more complete individual came from the Cochran farm and is designated as the type. It was embedded in a dark, red-brown, arenaceous shale. The bones were near the surface, most of them being covered by only a few inches of protective overburden. The entire area is heavily wooded, and consequently the skeleton has suffered from the penetration of tree roots.

The paratype was found in a fine yellow sand which locally contained masses of light gray clay nodules. This matrix is soft except around the bones themselves where it is extremely hard and difficult to work.

The preservation of both specimens leaves much to be desired. With few exceptions, there were no complete elements recovered. As a result, accurate measurement is practically impossible. However, a fairly complete understanding of the osteology of this unique reptile is furnished by the present specimens since, between the two, practically every part of the skeleton is represented. The following table lists all the more important bones:

TYPE—M.U.O. 8-0-S9	PARATYPE—M.U.O. 8-0-S8
Occiput	
Frontals	
Parietals	
Left jugal	
Left lachrymal	
Right squamosal	
Right postorbital	
Right ectopterygoid	
Articular portion of the left ramus	
Nine cervical vertbrae	
Six dorsal vertebrae	Two dorsal centra
Eight unattached dorsal spines	Four unattached dorsal spines
Two caudal centra	Thirteen caudal vertebrae
Three cervical ribs	
Five dorsal ribs	Eight dorsal ribs
One abdominal rib	
Two anterior chevrons	One anterior chevron
Left Coracoid	
Right and left pubes	Right and left pubes
Left ischium	
Distal end of the right femur	Proximal end of the left femur
Left tibia	Fragmentary left tibia
Right fibula	
Fragmentary left fibula	
Left astragalus	
	Left metatarsals II and III
	Left phalanx III (I)

GENERIC DIAGNOSIS

Order Surischia, Suborder Theropoda, Infraorder Carnosauria, Family Antrodemidae.

Acrocanthosaurus atokensis gen. et sp. nov.

This animal is a carnivorous saurischian of gigantic size and heavy proportions with massive and greatly elongated neural processes. The skull is of massive proportions, and the arcades are moderately heavy; orbits and postoribtal fenestra somewhat reduced; jugular foramen greatly enlarged; frontals and parietals solidly coosified and quadratosquamosal movement somewhat reduced; cervical centra opisthocoelous and of moderate length; pleurocentral cavities deep and well marginated; anterior dorsals distinctly opisthocoelous; medial caudals with supplementary neural processes; chevrons closed proximally by transverse bar, and exhibiting an anterior upward projecting process on each ramus; pelvic elements not coossified; pubis slender with broadly expanded distal termination; ischium straight, slender and elongate, somewhat expanded distally; tibia strongly bowed outward; metatarsal III somewhat constricted proximally by lateral elements.

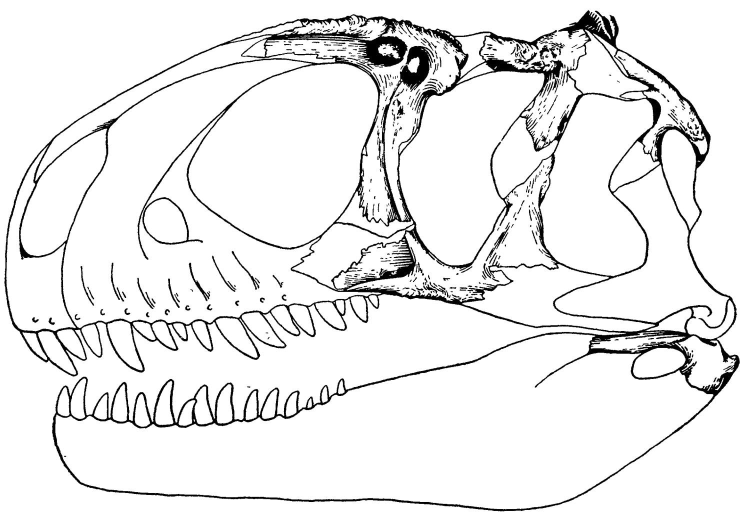

Fig. 2.—Restoration of the skull of *Acrocanthosaurus atokensis* gen. et sp. nov. Length of skull as restored about 896 mm. (restoration of the face and mandible, although based on comparison of several other large carnivorous dinosaurs, is hypothetical).

DESCRIPTION OF THE SKELETON

Skull.—The skull of *Acrocanthosaurus* is known only from remains of the type. The bones are, for the most part, well preserved although, as may be seen in Figure 2, the sutural areas are not generally complete. When found, the individual elements, with the exception of the occiput, frontals, and parietals, were disarticulated and widely separated; but careful comparison with the skulls of other large carnivorous dinosaurs has made their association and partial restoration possible.

In most instances, the developmental progressiveness as outlined by Gilmore (1920), Osborn (1912), and others is clearly shown in the skull of *Acrocanthosaurus,* although the large antorbital fenestra and expanded prefrontal as restored by the present writers are somewhat at variance with the views of those authorities.

Frontals.—When viewed from above, the frontals are subtriangular in outline and appear somewhat wider than in *Antrodemus.* The median suture between the two elements is poorly discernible, except in the most anterior region. The smooth superior surface is flat with only a low arching above the orbit. The fusion of the frontals with the parietals is complete, the contact being marked by a moderately rugose area on the superior surface of the skull. Laterally, however, this suture is sufficiently well marked to permit ready definition. Posteriorly, the frontals are greatly expanded transversely, uniting ventrally with the alisphenoids and laterally with the postorbital complex.

Gilmore (1920) states that the frontals in *Antrodemus valens* are "almost entirely excluded from the upper external boundary of the orbit, by the postfrontal and prefrontal bones." The prefrontals in *Acrocanthosaurus,* however, must have been of different proportions than those in *Antrodemus* and probably completely obscured the frontals in lateral aspect. Further evidence in support of this conclusion is furnished by the lateral edges of the frontals themselves which, although damaged, show indications of sutural contacts with other elements along their entire length.

Parietals.—When seen from above, the parietals are transversely expanded both anteriorly and posteriorly with a pronounced median constriction. The superior surface is slightly concave transversely, the raised lateral edges being separated from the almost vertical sides by a sharp antero-posterior angulation. There is no sagittal crest as in *Tyrannosaurus.* The bone exhibits no median suture, and the one between the frontals and parietals is indicated only by a slightly roughened surface above the line of contact. The dorsal extension of the supraoccipital crest is much less marked than in *Antrodemus,* and there is no supero-median notch as is seen in that genus. To the contrary, the superior edge of this crest in *Acrocanthosaurus* is transversely rounded and anteroposteriorly thickened at the summit. Laterally, the parietal appears as an almost vertical antero-posteriorly concave plate forming much of the median surface of the supratemporal fenestra.

Gilmore (1920) notes that in *Antrodemus* "the parietals are continued backward as a heavy overhanging, [the supraoccipitals], bluntly pointed projection." In the present skull, however, there is some question as to whether this projection actually belongs to the parietal or is part of the supraoccipital itself. At any rate, the lateral suture between the latter element and the parietal is clearly marked (there is no slender process interposed between the two elements as in *Antrodemus*) and appears to continue upward to the summit of the supraoccipital crest, in which case the parietal would be altogether excluded from the knob-like supraoccipital tuberosity.

Posteriorly, there is an elongate blade-like process that projects strongly outward and gently downward and backward overlapping the antero-superior surface of the paroccipital process.

Prootic.—The prootic is an elongate flattened element which partially separates the occipital and parietal regions of the skull. It bears a thin, blade-like, outwardly directed process which overlaps the antero-median surface of the paroccipital process with which it is solidly united. As in *Antrodemus* and *Tyrannosaurus*, it bounds the *foramen ovale* and the auditory fenestra. Whether the foramen for the exit of the seventh cranial nerve passes through the prootic, as in the majority of dinosaurs, or is only partially bounded by that element, as in *Antrodemus* and *Tyrannosaurus*, cannot be determined; but the writers are inclined to accept the latter condition as the more probable.

Jugal.—The jugal is sufficiently complete to give some idea of the size and shape of the orbit and lateral temporal fenestra. It is of the typical tri-radiate form, transversely thin, thickening ventrally below the orbit so that in this region the bone is triangular in cross section. The orbital border is more broadly rounded than in *Antrodemus*. The sharp ascending process, somewhat wider antero-posteriorly than in that genus, is directed slightly backward and tapers gently upward towards its union with the descending process of the post-orbital complex. The thin plate-like anterior portion is dorso-ventrally expanded and encloses an exceptionally large jugular foramen. The upper rim of this opening was evidently continuous with a longitudinal fossa on the outer surface of the lachrymal.

Lachrymal.—In lateral aspect, the lachrymal suggests the figure 7. It is more slender than in *Antrodemus*, the maxillary process being relatively longer and more highly constricted dorso-ventrally than in that genus. The rugose ridge-like superior edge exhibits no horn-like supraorbital tuberosity, but above the antorbital angle of the lachrymal and suturally united with it, there is a flattened rugosity slightly suggestive of a horn core. Two deep pneumatic cavities, of which the posterior one is somewhat the larger, are situated in the antorbital angle in much the same position as in other large carnosaurs. In outline, the inferiorly directed process forming the separation between the orbit and the large antorbital fenestra is a reversed sigmoid curve, its distal portion antero-posteriorly expanded and transversely flattened. On the outer surface of this process, there is a longitudinal furrow which opens anteriorly. It is deep superiorly, becoming more shallow below, but apparently was continuous with the upper edge of the jugular foramen when the jugal and the lachrymal were articulated. A similar fossa occurs in the lachrymals of both *Antrodemus* and *Ceratosaurus*, but in neither of these is it prolonged so far distally as in *Acrocanthosaurus*.

The imperfectly preserved lachrymal, when considered by itself, bears some resemblance to the homologous element in *Antrodemus*. However, when attempting to place it in the restoration of the skull, it was found to occupy a somewhat different position in relation to the other bones of the face. It was impossible to orient the bone as in *Antrodemus* and still retain the smoothly rounded antero-ventral border of the orbit. In placing it in juxtaposition to the jugal so that an acceptable relationship between the two bones was obtained, the forwardly directed maxillary process was elevated so that the front part of the skull was apparently disproportionately deepened in a dorso-ventral direction.

Postorbital Complex.—The postfrontal and postorbital are solidly fused, forming the massive postorbital complex. This bone is by far the most robust and massive element in the skull, being dorso-ventrally thickened and solid throughout. The upper part forms much of the roof of the orbit, overhanging that opening in a heavy eave-like brow-ridge. Although considerably roughened and tuberous above, there is no orbital rugosity as seen in *Tyrannosaurus*. The forwardly directed inferior process is expanded anteriorly so that it projects well into the orbital opening somewhat as in the deinodonts.

The sutural surfaces are dorso-ventrally thickened with the most anterior one facing directly forward. This condition differs markedly from that found in *Antrodemus*. Since no opposing surface is visible on the lachrymal of *Acrocanthosaurus*, it is concluded that this area on the postorbital complex must have been in contact with the prefrontal, which would then be interposed between the former elements; and consequently no pronounced supraorbital notch, as occurs in *Antrodemus*, would have been present.

Squamosal.—The squamosal is an irregular-shaped bone similar in outline to that of *Antrodemus* but differs from the corresponding bone in that genus in several important particulars. It is proportionately smaller with a greater antero-posterior expansion of the anteriorly directed inferior process. This expansion projects into the lateral temporal fenestra and results in some reduction in the size of that opening. The surface for the acceptance of the upper articular end of the quadrate is concave but is divided medially by a low antero-posterior ridge. The squamosal was not united with the quadrate, but the articular surface of the former would have permitted less movement between the two elements than in *Antrodemus*. There is evidence of the development of exostotic material in this articular cup which, if continued into later life, would have caused even greater restriction of the temporal movement.

Posteriorly, an elongate, flattened, process directed inward, upward, and slightly forward overlapping the antero-superior surface of the paroccipital process.

Basioccipital.—The basioccipital contributes largely to the formation of the smooth knob-like occipital condyle. However, due to the completeness of the coalescence of the bones in this region, it cannot be determined whether the condyle is composed entirely of this bone. A long narrow median process, more slender than in *Antrodemus*, extends downward from the condyle and unites laterally with the plate-like exoccipitals and the basisphenoids.

Exoccipitals and Paroccipitals.—When observed from behind, the exoccipitals appear as broad plates which, together with the paroccipitals, form much of the posterior aspect of the occiput. A median suture above the *foramen magnum* shows that the exoccipitals form the upper margin of that opening. The exact degree to which these bones contribute to the ventral border of the *foramen magnum* or to the upper part of the occipital condyle cannot be determined.

The wing-like paroccipital processes project strongly outward and backward and, in general, resemble very closely those elements in *Antrodemus* but are relatively shorter and somewhat more massive than in that genus. Laterally, on either side of the occipital condyle, there is a deep pit, in the upper part of which are the foramena for the exit of cranial nerves IX, XI, and XII.

Supraoccipitals.—The supraoccipitals form a large, vertically ovate, tuberous mass which project backward and may be readily seen in the lateral view of the articulated skull. They are solidly united with each other along the midline of the skull and are interposed between the parietals and join the exoccipitals ventrally. They are excluded from the border of the *foramen magnum* by the median junction of the latter elements. Superiorly, the supraoccipitals are expanded transversely and project posteriorly in a large knob-like tuberosity which continues downward as a median ridge to a point just above the median exoccipital suture.

Alisphenoids.—The alisphenoids are large outwardly directed lateral elements which unite superiorly with the frontals and parietals and posteriorly with the prootics. Superiorly, a strong transverse process is developed at right angles to the vertical and antero-posterior axes of the skull. The knob-like outer termination of this process is received into a corresponding concavity on the inner side of the postorbital complex. The sutures between the alisphenoids and the adjacent elements have, for the most part, disappeared through the solid coalescence of the bones in this region of the skull.

Orbitosphenoids and Ethmoids.—Anterior to the alisphenoids and below the frontal, there is an elongate, lateral, plate-like bone which encloses the foramen for the first cranial nerve. It appears to have been divided by a vertical suture into an anterior and posterior segment. The posterior element seems to represent the orbitosphenoid. If such is the case, the anterior bone, following Osborn (1912), is considered as being a probable ethmoid. No evidence of the presence of a presphenoid, as represented by Osborn (1912) in *Tyrannosaurus,* has been found in the material under consideration; but, as previously remarked, the sutural pattern of this cranium is, at many places, totally obscured. The supposed presphenoid of Osborn is here considered to be the anterior portion of the orbitosphenoid.

The combined elements (ethmoid and orbitosphenoid) unite posteriorly and laterally with the alisphenoids, superiorly with the frontals, and medially with each other. As in *Tyrannosaurus,* there is a vertical septum dividing the exit of the olfactory foramen into two suboval halves. The exit for the second cranial nerve is ventral in that portion of the orbitosphenoid which as Osborn suggests may represent the presphenoid (Osborn, 1912). This foramen is considerably smaller than in either *Antrodemus* or *Tyrannosaurus.*

Basisphenoids.—The basisphenoid is similar to that in *Antrodemus.* It is composed largely of an extensive lateral plate which partially encloses a very deep, triangular, forwardly-opening, cavity. Although the anterior edges of these bones have been destroyed in the present specimen, it is evident from the portions remaining that this cavity was not as deep antero-posteriorly or as vertically elongate as in *Antrodemus.*

The parasphenoid is developed upward from the apex of this triangular opening much as in the skull of *Tyrannosaurus* but differs somewhat from that genus in relative length. Its anterior extension is unknown.

The antero-ventrally directed basipterygoid process of the basisphenoid is more elongate than in *Antrodemus* and is bent strongly outward and bluntly terminated.

Ectopterygoid.—The ectopterygoid is an irregular U-shaped bone not unlike the element figured by Gilmore (1920) for *Antrodemus valens*. The diameter of the large open space between the posterior branches is, however, considerably wider in the present form.

Lower Jaw.—The remains of the lower jaw are too inadequate to permit detailed description, but portions of the articular, surangular, and angular can be recognized. Very interesting and altogether unexpected, is the presence of a fenestra in the surangular which occupies a position similar to the opening seen in the lower jaws of *Gorgosaurus* and *Tyrannosaurus*. Only a small portion of the upper margin of this fenestra is preserved so that its size and shape cannot be determined with certainty.

MEASUREMENTS OF THE SKULL

	Millimeters
Lachrimal	
Length of maxillary process	240*
Length of inferior process	165*
Least antero-posterior diameter of inferior process	42
Postorbital complex	
Greatest dorso-ventral diameter supraorbital ridge	36
Length of inferior process	104*
Greatest transverse diameter of superior surface	91
Greatest antero-posterior diameter of inferior process	52
Jugal	
Least dorso-ventral diameter below orbital rim	47
Least transverse diameter of anterior end	1.5
Height of jugular foramen	43
Width of jugular foramen	13
Greatest height of ascending process	203
Width of ascending process at midlength	57
Greatest transverse diameter below orbit	41
Squamosal	
Transverse diameter articular cup	39
Antero-posterior diameter of articular cup	48
Antero-posterior diameter of inferior process	38
Length of parietals and frontals	227
Greatest transverse diameter of frontals	173
Transverse diameter of parietals (posterior)	185
Transverse diameter of parietals (anterior)	173
Least transverse diameter of parietals	34
Transverse diameter across alisphenoids	215
Height of skull from the basipterygoid process to top of frontals	260
Transverse diameter of *foramen magnum*	35
Vertical diameter of *foramen magnum*	27
Breadth across paroccipital processes	344

* Measurements of incomplete bone.

VERTEBRAL COLUMN

Cervical Vertebrae.—Of the ten more or less anterior presacral vertebrae preserved in the type specimen, nine belong to the neck. When found, only cervicals 8 and 9 and dorsal 1 were articulated, but the remaining seven vertebrae were closely associated with them. All of these bones are slightly distorted and damaged by tree roots and ground acids, but they are sufficiently well preserved to permit the accompanying restoration.

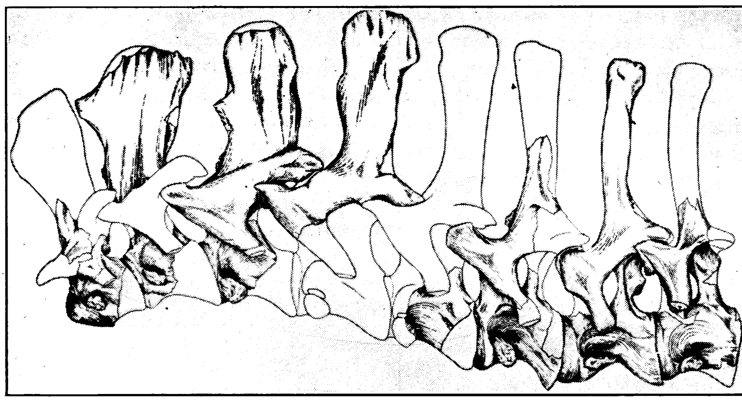

Fig. 3.—Cervicals 3 to 9 and dorsal 1 of *Acrocanthosaurus atokensis* gen. et sp. nov. about 1/9 natural size (for exact measurements see table on page 709).

Only a small fragment of the atlas, probably the intercentrum, was recovered. The axis is represented by a similar fragment. The neural canal was relatively larger than in the succeeding cervicals, and there is an indication of a well developed odontoid process.

The remaining cervicals are lightly constructed and exhibit exceptionally long spinous processes. The centra are strongly opisthocoelus, the anterior ball-like articular end almost filling the corresponding posterior concavity of the preceding element. They are somewhat longer than high, deeply excavated laterally, transversely expanded, being slightly wider than high, and, with the exception of the third, exhibit no indication of a ventral keel. The pleurocentral excavations are deep and sharply circumscribed. Laterally, a small oval foramen is situated just above the parapophysis in the deep anterior part of the pleurocentral cavity. This foramen, which apparently leads into the hollow of highly concellous interior of the centrum, becomes progressively larger and more elongate in each succeeding vertebra; but its relation to the parapophysis remains essentially the same throughout the series. Beginning with the sixth or seventh cervical, a second smaller ovate foramen appears, situated a few millimeters above and somewhat posterior to the larger one just described.

The diapophyses are elongate processes directed backward and strongly downward. In the more anterior vertebrae, they are applied laterally close to the centra and the neural arches and terminate well below the level of the neurocentral suture. In the more posterior elements, however, these processes diverge with increasing sharpness from the body of the vertebrae and terminate progressively higher in relation to the neurocentral suture. They are supported and strengthened by oblique, buttressing laminae which arise both anteriorly and posteriorly just above the neurocentral plane and converge upwardly, finally meeting each other near the tubercular facet on the ventral surface of the diapophysis.

The parapophyses are broad, rounded, processes that project strongly outward from the lower part of the centra. They are less elongate than in *Antrodemus,* and when seen from the side they exhibit a marked change in position in the articulated series. On the third cervical, the parapophysis is situated well up on the side of the centrum and just posterior to the lip-like rim of the anterior articular surface. The capitular facet faces directly outward. In the medial section of the neck, it increases greatly in size and shifts downward so that in some instances more than one-half of the area of the capitular facet appears below the ventral border of the centrum. Posteriorly, however, it returns to a somewhat higher position but still remains well below the center of the centrum. In cervicals 7, 8, and 9, the parapophyses project strongly backward and the capitular facets look outward, backward, and somewhat downward.

The neural canal is relatively small throughout the series, its height only slightly exceeding its transverse diameter.

Laterally, the neural arches are plate-like and of moderate length. They are transversely thickened in the center, resulting in a moderate constriction of the neural canal at this point. In cervicals 7, 8, 9, there is, in addition to the oblique diapophyseal laminae mentioned above, a strong vertical bar which arises from the posterior part of the neurocentral area and joins above with the downward directed median portion of the posterior zygopophyses. It forms the posterior border of a vertically elongate opening which apparently passes through the sides of the neural arches into the neural canal just posterior to the parapophysis.

The prezygopophyses are large massive processes, the flat articular surfaces of which look upward and inward. In all cervicals posterior to the axis, they overhang the centrum; but their forward projection diminishes towards the base of the neck, and in the ninth the anterior termination almost coincides with the anterior end of the centrum.

The postzygopophyses overhang the centra but to a somewhat lesser degree than in *Antrodemus.* Well-developed epipophyses are present on the superior surfaces of the postzygopophyses. They are most noticeable on the fifth cervical where they project backward well beyond the posterior termination of the postzygopophyses. The epipophyses diminish rapidly in prominence towards the base of the neck and disappear altogether with the ninth cervical.

The neural spines of *Acrocanthosaurus* are the most striking feature of the entire skeleton. Those of the anterior cervicals are broad flat plates of bone varying in length from two to almost three times the height of the vertebral centra. They become broader in succeeding vertebrae, reaching their maximum expanse in number 6. In this vertebra, there is a rather sudden transition from the broad plate-like process of the more anterior elements to a more elongate, antero-posteriorly constricted spine with a rounded and broadly expanded summit. Posterior to the seventh cervical, the general form again changes abruptly. The spines become greatly thickened transversely and increase slightly in length. Concurrent with the increase in length, there is a marked decrease in the antero-posterior dimension. The resulting slender-pointed processes are altogether unlike the spines of any other known carnosaur. In cross section, the spines of cervicals 7, 8, and 9 are broadly U-shaped at the base and subround at the summit. They are inclined slightly forward, an adaptation doubtless required to facilitate upward movement of the neck.

In addition to the spines, numerous other less spectacular differences between the cervical vertebrae of *Acrocanthosaurus* and those of other carnosaurs are worthy of mention. The pronounced opisthocoelous character, the elongation of the centra, a more open and lighter constriction, and the sharply circumscribed pleurocentral excavations readily distinguish these cervicals from those of the later Upper Cretaceous deinodonts. The latter generally exhibit a flattened opisthocoelous type of articulation, a reduction in length of the centra, a corresponding increase in the height of the centra, more massive proportions, and a more solid construction.

Differences from Jurassic theropods are less pronounced. The cervicals of *Acrocanthosaurus* may, however, be distinguished from those of *Antrodemus valens* by the greater elongation of the centra and a corresponding decrease in height resulting in a somewhat more slender appearance in the former genus. The neural arches are not as broad antero-posteriorly as in the Morrison form, and the pleurocentral cavities are somewhat deeper and more sharply circumscribed. The diapophyses are more elongate, and the parapophyses project outward to a slightly greater degree than in *Antrodemus*. The opisthocoelous character, although developed equally in both forms in the anterior and medial cervicals, diminishes more rapidly towards the base of the neck in *Antrodemus*. In the Trinity animal, the posterior cervicals exhibit a strong opisthocoelous character suggestive of the condition present in *Megalosaurus* (*Streptospondylus*) *cuvieri* (Owen) from the Malm of England.

The criteria listed above for distinguishing *Acrocanthosaurus* from *Antrodemus* are equally applicable to the true European megalosaurs, although the centra in the present form are proportionately less elongate than in that group. The resemblance between the Oklahoma genus and *Megalosaurus* (*Streptospondylus*) *cuvieri* (Owen) is striking, although the centra in the present form are relatively lower than in that genus. The depth and margination of the pleurocentral cavities and the persistence of the opisthocoelous nature are practically identical in the two forms. The neural arches, however, are much more narrow antero-posteriorly in the present animal.

Similarity to the cervicals of *Spinosaurus aegyptiacus* Stromer is considered of little diagnostic importance. All other bones of the two animals are so dissimilar that any resemblance in isolated parts of the skeletons is coincidental and of no diagnostic value.

The number of cervical vertebrae in *Acrocanthosaurus* is unknown, but it is assumed to have been nine as in related genera. The break between the cervicals and the first dorsal is much more gradual than in those forms.

MEASUREMENTS OF THE CERVICAL VERTEBRAE (in mm.)

Vertebra	Length of Centrum	Height of Centrum	Height of Spine
3	96	66	------
4	98	73	214
5	123	87	200
6	------	------	242
7	153	83*	------
8	158	117	--- --
9	168	115*	291

* Measurements of incomplete bone.

Dorsal Vertebrae.—The tenth presacral vertebra is provisionally identified as the first dorsal, but it might be more appropriately considered as a cervico-dorsal and transitional between the cervical and dorsal series. Like the cervicals, it is strongly opisthocoelous; and the centrum is longer than high. The parapophyses are set low on the sides of the centrum, and the diapophyses have not yet risen to a horizontal position. The pleurocentral excavations are deep and sharply circumscribed anteriorly with the two small foramena situated much as in the posterior cervicals. It is, however, in agreement with the dorsals in the higher position of the zygopophyses, neither of which overhangs the centrum. The diapophyses are situated relatively higher than in the preceding vertebra, and there is a suggestion of the presence of a hyposphene on the post-zygopophyses. The anterior zygopophyses are robust, upwardly directed processes, the articular surfaces of which look upward and only slightly inward, in marked contrast to those of the cervicals in which they slant sharply inward and downward. Although this is the last opisthocoelous vertebra preserved, the depth of the posterior cup indicates that the second dorsal also possessed this characteristic; and it appears probable that the condition continued as far back as the fourth or fifth, therein differing from *Antrodemus* where the opisthocoelous character is lost in the neighborhood of the second or third dorsal vertebra.

Of the remaining five vertebrae in the dorsal series, only three are sufficiently well-preserved to permit direct comparison with similar elements of other genera. Three of them appear to belong in the neighborhood of dorsals 6 to 9, while two large amphicoelous centra, possibly belonging to numbers 13 and 14, occupy a more distal position in the series.

The centrum of the sixth dorsal is plano-concave, while those posterior to it become progressively biconcave, finally reaching a pronounced amphicoelous condition in the two distal elements. All are deeply constricted laterally and ventrally and exhibit the pronounced flaring of the end typically present in other large theropods. The pleurocentral excavations are large and, although moderately deep, are not well marginated. Each contains a longitudinally ovate foramen which is divided by a thin vertical lamina into two subequal halves. The anterior opening thus formed is decidedly the larger of the two and is situated slightly below the smaller one. All centra are higher than long, though the difference in these dimensions is not readily apparent in the more posterior elements. There is no definite neurocentral suture, but a rather persistent fracture in the vicinity of the base of the neural arch occurring in the three anterior vertebrae may indicate the position of this junction.

The parapophyses are located low on the sides of the neural arch, but, in all except the sixth, appear to lie well above the level of the neurocentral suture. They are robust, relatively longer than in *Antrodemus*, project strongly outward, somewhat downward, and terminate in a slightly expanded concave capitular facet.

The transverse processes are all incomplete, but supposedly they were directed sharply upward and somewhat backward in the anterior elements. Each was supported from below by a broad but thin lamina which arises abruptly from the superoposterior surface of the centrum. Another supporting lamina arises from the anterior and posterior zygopophyses and converges terminally, contributing greatly to the broad, flat, superior surface of the process.

The prezygopophyses are massive processes, the articular surfaces of which look directly upward. As mentioned above, each give rise laterally to a broad plate-like lamina which forms the anterior edge of the transverse process. Medially, they are separated by a deep vertical groove which receives a corresponding vertical blade-like process that projects downward from the posterior zygopophyses of the preceding vertebra.

The postzygopophyses are opposites of the prezygopophyses. They possess strong hyposphene articulation which, together with the neural spines, must have greatly reduced the mobility of this part of the vertebral column.

Several incomplete neural spines were recovered, and it is entirely possible that at least some of them belong to the vertebrae just described; but all attempts at actual association have proved disappointing. The same peculiar conditions present in the spines of the cervical vertebrae are here carried to even greater extremes. All are poorly preserved, but one which measures about 300 mm. in length furnishes some idea of the general character of the processes. The exact position which this spine would occupy is, as previously stated, undeterminate; but a comparison of its dimensions with those of the cervicals and anterior caudals suggests that it belongs in the anterior or medial part of the back. It is elongate and massive, very similar, in fact, to the spines of *Altispinax* (*Megalosaurus*) *dunkeri* (Dames) as figured by Owen (1853-1864). Near the base, it is antero-posteriorly constricted, measuring only 76 mm. in that direction. Its fore and aft dimension, however, increases gradually upward, the antero-posterior diameter of the summit being 98 mm. The areas for muscular attachment are extensive and particularly well-developed on the anterior and posterior sides where a rugose, vertical, median lamina separates two narrow but deep lateral grooves.

The dorsals of *Acrocanthosaurus* may be distinguished from those of

Tyrannosaurus, Gorgosaurus, and the other Upper Cretaceous theropods of North America by the more elongate centra and the larger but much more shallow pleurocentral cavities. The well developed hyposphene is absent in *Tyrannosaurus.*

The similarity between *Acrocanthosaurus* and *Antrodemus* is more apparent in the dorsal than in the cervical vertebrae. The relative proportions are practically the same in both genera, but the pleurocentral excavations remain somewhat deeper and the parapophyses relatively shorter in the former genus. It is probable that the anterior dorsals were more strongly opisthocoelous in *Acrocanthosaurus,* still agreeing in that respect with *Megalosaurus* (*Streptospondylus*) *cuvieri* (Owen).

The neural spine is more highly constricted antero-posteriorly and more elongate than in the dorsal vertebra of *Megalosaurus parkeri* figured by von Huene (1926). Although much longer than the dorsal spines of *Antrodemus,* it resembles them in its general construction. Among the Carnosauria, however, the spines of the Oklahoma animal most nearly resemble those of *Altispinax* (*Megalosaurus*) *dunkeri* (Dames) but, as preserved, is relatively shorter than in that form. The general shape of the centra and neural arches is similar in the two animals, but the pleurocentral cavities in the preserved dorsals of *Acrocanthosaurus* are relatively longer and somewhat deeper than in the European form; and the flaring of the articular ends is more pronounced in the former.

The dorsals of *Acrocanthosaurus* are so different from those of *Spinosaurus aegyptiacus* Stromer that no comparison is necessary.

MEASUREMENTS OF THE DORSAL VERTEBRAE (in mm.)

Vertebra	Length of Centrum	Height of Centrum (Posterior End)
1	153	......
6	107	120
7	110	125
8	......	126
13	128	136
14	125	137

Caudal Vertebrae.—Three separate series of caudal vertebrae were recovered with the paratype. These constitute the only articulated elements found in either specimen, but the absence of several vertebrae which belong between these segments makes their position within the articulated series somewhat uncertain. Although it is impossible to determine the exact number of elements comprising the tail of *Acrocanthosaurus,* it appears that the number of vertebrae was somewhat greater than in *Antrodemus,* if Gilmore's (1920) estimate of 45 caudals for that genus is correct.

The largest of the fifteen vertebrae represent caudals 1, 2, 3, and 4. It is probable, judging from the degree of taper and the diminution in the height of the centra, that the next group of four elements belongs in the vicinity of caudals 9 to 12. The more posterior series consisting of seven more or less complete centra and attached neural arches probably should be introduced in the neighborhood of numbers 17 to 23.

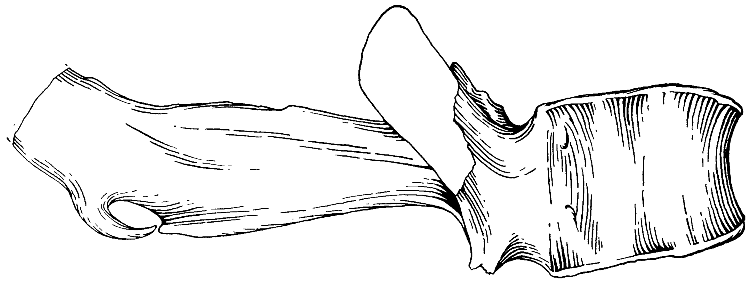

Fig. 4.—Third caudal vertebra of *Acrocanthosaurus atokensis* gen. et sp. nov. 1/6-plus natural size (for exact measurement see page 714).

The centra of the first four caudals are higher than long, but in the more distal elements the height diminishes more rapidly than the length; and, finally, in caudals 9 to 23 the centra are from 12 to 37 millimeters longer than high. The constriction of the lateral and ventral surfaces is less pronounced than in *Antrodemus,* and the resulting flaring of the ends is correspondingly less than in that genus. The pleurocentral excavations are shallow, elongate, and are situated somewhat above the midheight of the centra. The centra of the second and third caudals are gently procoelous and slightly wedge-shaped in lateral aspect, being narrow and wide above. Although the posterior face is very gently convex, the anterior surface is deeply concave. The exact point at which the articulation becomes biconcave is not known, but it is well in advance of the ninth caudal for, in that vertebra, the ends are decidedly concave and subequal in depth. A longitudinal groove, on the ventral surface of the medial caudals is scarcely noticeable on those more anterior in position. The ventral articular lips of all but the first caudal are beveled for the insertion of the chevrons, but there are no true chevron facets.

The neural arches are strongly constructed and almost as long as their respective centra. They are low, and the neural canal is small. The transverse process of the incomplete first caudal is extremely broad and flat. It projects strongly upward and backward and shows every indication of having underlain the ilium, though there was probably no osseous connection between the two elements. The transverse processes of the remaining vertebrae are long and well-developed far back along the tail. They are broad antero-posteriorly, dorso-ventrally flattened, and project strongly outward. The free or outer ends show a strong tendency toward flaring and upward bending. In the anterior caudals, they originate on the sides of the neural arches and project backward at an angle of about 50 degrees. In the more posterior elements, however, their position shifts gradually downward onto the sides of the centra, and the angle between the transverse and longitudinal axes constantly approaches 90 degrees. However, in none of the caudals do the transverse processes appear below midheight on the centrum.

There are only two complete zygopophyses preserved, but from these and several fragments of others, it is evident that the prozygopophyses were somewhat less elongate than in *Antrodemus*. Both anterior and posterior zygopophyses overhung the centra in all of the vertebrae preserved. As in the cervicals and dorsals, the articulation between the caudals was greatly strengthened at the expense of freedom of movement. There is a definite hyposphene-like process projecting downward from the posterior zygopophyses of the first, second and third vertebrae.

The neural spines are elongate but, unlike those of the dorsal series, are flat plate-like processes devoid of heavily sculptured surfaces for the attachment of muscles. In the third caudal, the base of the spine is antero-posteriorly constricted. It broadens gently upward to a point well above midlength where it again decreases somewhat more rapidly in width. The character of the summit is unknown, but at least a slight transverse expansion is indicated. At the widest part of this spine, an ovate foramen pierces the anterior surface of the bone and separates a small downward-projecting finger-like process from the main body of the spine. The progress in the development of this opening in the succeeding vertebrae cannot be observed, but it is assumed to have involved rapid deepening and widening. In caudals 10, 11, and 12, the opening has disappeared; but in its place there is a peculiar step-like development of the anterior edge of the spine. This situation results in the lower part of the spine being nearly twice the width of the upper half. In this region of the tail, the summits of the spines are rounded and expanded antero-posteriorly; but there is very little transverse enlargement. In the remaining series of seven vertebrae, only one spine is preserved. It marks the ultimate in the development of the processes which has been followed throughout the tail. The step-like notch in caudals 10 to 12 has become a wide vertical cleft dividing the spine into two segments, of which the anterior one is much the smaller. The purpose and functions of this small upward projection are unknown. It was at first thought to be the result of a pathological condition; but the construction of the neural arches in the adjacent vertebrae and the general absence of exostosis on the other elements of the skeleton, together with the construction of the other spines in *Acrocanthosaurus*, lead to the conclusion that the development of double spines in these vertebrae represents a normal condition. Evidence further substantiating this assumption has been furnished by Mr. LeRoy Kay (personal communication) who states that in the Carnegie Museum skeleton of *Antrodemus* a similar step-like development is seen in the spine of the sixth caudal and that some type of bifurcation occurs in the eleventh. A similar condition, but developed to a smaller degree, occurs in the caudal vertebrae of *Segisaurus hallii* Camp (Camp, 1936). With the above exceptions, no similar condition is known, although the anterior caudals of *Ceratosaurus nasicornis* do bear some resemblance to caudals 10 to 12 of *Acrocanthosaurus*, a condition which is apparently produced by some pathological condition in the former individual.

The caudal vertebrae of *Acrocanthosaurus* may be distinguished from those of Upper Cretaceous theropods by the general dimensions of the anterior centra which, in the Trinity animal, are higher than long. A noticeable difference between the caudals of *Antrodemus* and *Megalosaurus* is the smaller degree of constriction of the ventral surface in the anterior elements. The transverse processes were apparently somewhat shorter than in *Megalosaurus* (*Streptospondylus*) *cuvieri* (Owen) and, as in that genus, were present far down the tail. As noted above, there is some similarity between a number of the neural spines of *Acrocanthosaurus* and those of the anterior caudals of *Ceratosaurus nasicornis*. With this notable exception, little agreement can be found, the anterior centra in the latter being longer than high and deeply concave below. The spines of the anterior vertebrae of *Acrocanthosaurus* are, so far as known, unlike those in other theropods; but the spines of *Altispinax* might well exhibit many points of similarity. The spines of *Megalosaurus parkeri* Huene are much shorter and are inclined backward, whereas in the present form they are almost vertical in position.

MEASUREMENTS OF THE CAUDAL VERTEBRAE (in mm.) M.U.O. 8-0-S8

	Length of Centrum	Height of Centrum	Height of Spine	Max. width of Spine	Total Height of Vertebra
1	......	137	......	......	......
2	128	128*	......	......	......
3	138	170	422*	123	641*
4	140	162	392*	125	558*
9	149	......	......	......	......
10	146	134	291	89	434
11	141	125	247	84	396
12	140	116	190	95	330
18	......	105	......	......	......
19	131	103	......	......	......
20	134	97	......	......	......
21	135	94	......	......	......
22	......	94	142	......	238
23	124	81	......	......	......

* Measurements of incomplete parts.

Discussion of the Vertebral Spines.—Following the discovery of *Spinosaurus aegyptiacus* Stromer, in 1912, much speculation has centered around the peculiar elongation of the neural spines in the Carnosauria. Stromer (1915) has ably discussed the unique development in *Spinosaurus* but failed to reach a definite conclusion as to its origin or functions. Since the relationship between *Spinosaurus* and *Acrocanthosaurus* is remote, no further allusion to the former genus is necessary, except possibly to note that whatever the functions of the neural spines in the Egyptian animal, they must have differed greatly from those in *Acrocanthosaurus*.

Several other instances of eccentric spinous development may be seen in the ornithopods *Hypacrosaurus altispinus* Brown and *Bactrosaurus johnsoni* Gilmore, as well as in the European theropods *Altispinax dunkeri* (Dames) and *Megalosaurus parkeri* Huene. A further occurrence is reported by Case in *Coelophysis,* from the Triassic of Texas (Case, 1927). In all of these animals, the neural processes are relatively more elongate than in any of the closely related genera. Apparently in all, the spines were deeply embedded in a thick mass of muscle similar in nature to the high withers in the recent *Bison;* and the animals themselves must necessarily have differed somewhat in appearance from the more "conventional" genera in having a high, thick dorsal ridge. Such a condition is readily adapted to *Acrocanthosaurus,* the spines of which are massive and rugosely sculptured. The suggestions made in connection with the Permian pelycosaurs *Edaphosaurus* and *Dimetrodon* that the spines might have supported a high, fin-like median ridge, or have even been separate spikes in the center of the back, are certainly unacceptable insofar as the present form is concerned.

Environmental adaptation may have played some part in the development of the elongate spines, but the extent of its influence is unknown. It can only be observed in the light of present knowledge that all of the contemporaneous forms from the same horizon and locality apparently exhibit a similar development, and thereby differ from closely allied genera from other parts of the world. The spines of the caudal vertebrae suggest a very high and flat tail which might conceivably have been developed in connection with a semi-aquatic habitat, although the reasons for the adoption of such a habitat by a large and specialized theropod are admittedly obscure.

A mechanical explanation is only little more acceptable than the suggestion of a large theropod with semi-aquatic habits. As mentioned before, the elongation of the spines and the consequent development of strong hyposphene articulation even in the anterior caudals could only have resulted in considerable loss of mobility in the vertebral column. Increased strengthening of the back in support of a massive skull does not appear to be the answer in view of the fact that in *Acrocanthosaurus* the head was proportionately smaller than in *Tyrannosaurus.* In the latter genus, however, the spines are certainly no longer than in the relatively smaller skulled *Antrodemus.*

The question of sexual characteristics necessarily arises whenever peculiar structural development is found in only a few members of a large and well-known group of animals. That sexual differentiation may well present the solution to the problem is readily admitted, but the question, insofar as the dinosaurs are concerned, seems to be of purely an academic nature; and it appears highly improbable that a reliable criterion for sex determination will ever be recognized among these animals.

A partial explanation of the excessive development of the spines may indicate a genetic trend for which no reversal is provided.

Chevrons.—The first chevron was apparently borne between the second and third caudal vertebrae. Of three fragmentary elements recovered only an anterior one from the paratype is sufficiently well preserved to permit critical examination. This bone is similar to its homologue in *Antrodemus* but was less strongly decurved. A small upward projecting spur on the anterior side of each ramus, although present, is not as highly developed as in the *Antrodemus* chevron figured by Gilmore (1920). Such a projection is apparently lacking in *Megalosaurus*. The two rami are joined proximally by a wedge-shaped transverse bar which protruded slightly between the vertebral centra when articulated. There are no true condyles as are found in the deinodonts. The greatest transverse diameter of the proximal end is 93 mm.

Ribs.—The ribs of both specimens are poorly preserved, the majority being represented only by fragmentary sections of the shafts. Proximal ends of the cervical ribs are unknown, but several more or less complete shafts are preserved. Those from the anterior part of the series are extremely long and slender with a tendency toward a gentle outward and downward bending of the distal portion. The more posterior elements are much shorter, heavier, and more strongly decurved.

No anterior dorsal ribs are recognizable, but several from a more posterior position are fairly well preserved. In each the proximal end is broadly expanded inwardly and extends strongly upward, resulting in the development of an elongate neck which is terminated by a moderately enlarged convex capitulum. The tubercle becomes smaller in each succeeding rib but is still present, though weakly developed, in the last. It is, however, generally poorly differentiated, there being little or no postero-dorsal continuation and only a slight antero-dorsal expansion from the antero-external edge of the shaft. In some of the medial elements, there is a small flange-like process directed upward and outward which joins the antero-dorsal surface of the tubercle.

When viewed laterally, these ribs are noticeably more slender than in *Antrodemus*, although the general contours are similar in the two forms. A short distance below the proximal end, the more anterior ribs are somewhat enlarged, but below this expansion the shafts taper gently downward.

In cross section, the shafts of all but the most posterior ribs are sharply angular proximally due to the presence of deep longitudinal grooves and sharp anterior and posterior continuations of the flat outer surface. At midlength they are subovate to round and finally become antero-posteriorly oval to subround. The only distal termination preserved is slightly enlarged.

Gastralia.—The only abdominal rib preserved is strongly curved, subround in cross section, and greatly enlarged at its inner end where it was overlapped by the next segment. It is composed largely of a highly porous spongiosa, herein differing markedly from the ribs themselves which, like the other bones of the skeleton, are smooth and surficially dense.

The number of elements comprising the abdominal cuirass is unknown; but, in view of other progressive characteristics exhibited by the skeleton of *Acrocanthosaurus*, it might be inferred that there had been some reduction in the total number. Such a supposition is further enhanced by the fact that this particular rib is very similar to those of *Gorgosaurus libratus* Lambe (1917). It is longer and more slender than in *Antrodemus*.

Pectoral Girdle.—Coracoid. The pectoral girdle of *Acrocanthosaurus* is represented by a poorly preserved left coracoid. This bone is higher than wide and somewhat shortened antero-posteriorly with smoothly rounded superior and anterior borders. Inferiorly, there is a broad notch separating the thickly marginated glenoid fossa and the ventral hook-like extension of the anterior border. A small ovate tuberosity is situated externally a short distance above the apex of this notch and is reflected internally by a deep depression. Outwardly, the coracoid is irregularly convex in all directions, while inwardly it is correspondingly concave. It is thin along the superior and anterior edges but thickens inferiorly and posteriorly towards the glenoid cavity and the scapular surface. It cannot be determined from the present specimen whether the coracoid foramen was entirely enclosed within the coracoid, but it appears that it was situated nearer the coraco-scapular suture than in either *Antrodemus* or *Gorgosaurus*.

Pelvic Girdle.—The pelvis of *Acrocanthosaurus* is represented in the present collection by the incomplete pubes and left ischium from the type and the well preserved pubes of the paratype.

Pubis.—The pubis is similar to that of other large North American carnosaurs but is of relatively more slender proportions. It is altogether unlike the pubes of the more primitive megalosaurs of Europe. In lateral aspect, the shaft is elongate, straight, and slender. It is inclined downward and forward meeting the broadly expanded "foot" at an angle of 35 degrees. When viewed from the front, it is concave inwardly with a medially projecting lamella which is in contact, though not fused, with its mate in the living animal. Some 300 mm. from the distal end these lamelli separate forming an elongate median aperture 160 mm. in length. Below this aperture, the fusion of the distal ends begins posteriorly.

The distal end is expanded antero-posteriorly into the characteristic triangular foot-like termination which in *Acrocanthosaurus* is somewhat narrower vertically than in *Antrodemus*. In the paratype, the pubes are solidly united at the pubic symphysis; but in the type (a younger individual) there is an oval aperture 150 mm. in length along which the two bones are not in contact with one another. From below, the outline of the fused "foot" is similar to that of an isosceles triangle, the short leg being anterior. The rugose inferior surface is flat in all directions with the edges rounded and somewhat transversely expanded.

Ischium.—The preservation of the ischium is of particular interest in that it offers the only evidence concerning the articular relationships of the bones of the pelvis.

The ischium is Y-shaped but differs markedly from that of *Antrodemus* and *Megalosaurus* in its relative proportions, the proximal end being more massive and the shaft more slender than in either of those genera. It is proportionately somewhat more elongate than in the related forms, being nearly, if not quite, as long as the pubis. There is no lateral ridge on the proximal end as in *Megalosaurus parkeri* Huene. The obturator process on the ventro-internal edge is similar in shape and position to that in *Antrodemus*. The articular surface of the expanded pubic process is smooth and marginally rounded, and it is therefore inferred that the pelvic elements were not coossified. In cross section, the shaft is subovate proximally but becomes narrowly oval distally. An elongate tuberosity, more prominent than in *Antrodemus* but not approaching the angulation seen in *Megalosaurus,* is situated on the supero-external edge of the shaft just below midlength.

The distal end is enlarged, but the degree of the flaring is not determinable from the present specimen.

Hind Limb.—The femora and tibii are incomplete in both specimens, and consequently the relative proportions of the hind limb are somewhat conjectural. The estimations of the length of the separate elements are based on a comparison of the fairly complete fibula and metatarsals with those of other genera to which they bear the closest resemblance. All of the bones of the leg, with the exception of the astragalus, are considerably lightened by the presence of unusually large medullary cavities.

Femur.—The proximal end of the femur is massive with the enlarged, smoothly rounded head directed sharply inward and slightly upward so that its superior surface rises above that of the greater trochanter, with which it is uniformly contiguous. When seen from above, the head and greater trochanter are broadly rounded anteriorly and distinctly concave posteriorly in such a way that the head is somewhat broader than the trochanter in fore and aft direction. The blade-like anterior trochanter extends upward and trends somewhat obliquely from the antero-external edge of the bone downward onto the anterior surface of the shaft. It is strongly developed forward and is separated proximally from the greater trochanter by a broad intertrochantric fossa. Distally, on the anterior edge of this process, there is yet another smaller crestlike tuberosity which projects sharply outward in opposition to the trochanter itself, which has a tendency to bend inward along its anterior edge.

With the exception of a lighter construction probably occasioned by the immaturity of the type, the distal one-fourth of the femur in *Acrocanthosaurus* is very similar to that in *Antrodemus,* but the shaft was apparently less strongly bowed antero-posteriorly in the former genus. The inner and outer condyles are of nearly equal proportions, the tibial condyle being more compressed transversely than in either *Antrodemus* or *Megalosaurus.* Posteriorly, the intercondylar fossa is deep and narrow, whereas on the distal and anterior surfaces it is broad and only slightly concave. The slightly roughened area for the attachment of the femoro-tibialis muscle is a flat, inwardly expanded, longitudinally ovate surface, the angular internal edge of which is continuous with that of the inner condyle. The estimated length of the femur in the paratype is 1153 mm.

Tibia.—The tibia of *Acrocanthosaurus* differs greatly from tibiae of other carnivorous dinosaurs. The angle at the distal articular end, formed by the elongation of the malleolus, is larger than in most of the Jurassic and Cretaceous Carnosauria. The shaft is more strongly bowed outward than in any known allied genus. It is more slender than in *Antrodemus valens* or *Megalosaurus.*

The tibia is slender and moderately expanded transversely at the distal end. When seen from the front, the shaft is bowed strongly outward, the greatest curvature occurring in the lower one-half of the bone, where it is accentuated by the expanding inner malleolus. In lateral aspect, the tibia is gently curved posteriorly with the upper part bent strongly forward, giving rise to the cnemial crest. The anterior surface is transversely flattened with an elongate, shallow, longitudinal depression along the lower one-half of the bone. The posterior surface is gently rounded transversely and meets the flattened anterior face in a pronounced antero-external angularity. In cross section, the upper part of the shaft is subround, becoming distinctly ovate below and finally, in the distal one-fifth of the bone, changing to a slightly cresentic condition, transversely concave in front and angularly convex behind.

Some 560 mm. above the distal end, the sharp comb-like fibular crest arises abruptly from the antero-external surface of the shaft. Although not completely preserved, it appears probable that this process originally resembled the homologous structure in the Deinodontidae but was apparently somewhat smaller proportionately than in the members of that family.

The distal end is expanded transversely into two arris-like malleoli, of which the external one is decidedly the longer. The shallowly concave area on the anterior face, which was overlain by the ascending process of the astragalus, is broadly triangular in outline and is roughened by numerous longitudinal ridges. A small rugose tuberosity occurs on the anterior side of the external malleolus where the distal end of the fibula was closely applied to the tibia.

Fibula.—The fibula is a very slender, transversely compressed bone. Its lateral surface is smoothly rounded. The upper one-fourth is greatly expanded antero-posteriorly, and the proximal end is broadly triangular in outline. Like the tibia, the shaft of the fibula is strongly curved backward in the center. It is concave inwardly and has a pronounced outward curvature at either end. (Some of the bending may be due to post-mortem distortion.) The fibular process, situated on the anterior edge of the shaft about 285 mm. from the proximal end, is a moderately elongate tuberosity.

The distal end is antero-posteriorly rounded and only slightly enlarged. Its anterior edge is slightly flared, forming a thin flange-like process which overlies the anterior surface of the outer malleolus of the tibia.

Pes.—The poorly preserved astragalus does not lend itself to a detailed discussion; it appears, however, to be similar to that of *Antrodemus*.

The pes in *Acrocanthosaurus* is somewhat more slender than in *Antrodemus*, the third metatarsal being slightly flattened by numbers II and IV. This transverse compaction does not, however, approach the extreme flattened condition of this bone in the deinodonts.

Proximally, the second metatarsal is expanded antero-posteriorly. When seen from above, the shallow concave proximal surface is roughly triangular in outline, with the longest leg of the triangle being applied laterally to number III. The shaft, which is closely applied to that of metatarsal III along three-fourths of the length of the latter, is not as sharply divergent distally as in *Antrodemus*. On the anterior side of the angular left edge of the shaft some 60 mm. from the proximal end, there is a pronounced notch, below which a small sharp-edged, flange-like, tuberosity overlaps the shaft of the third metatarsal. On the posterior side, 180 mm. from the distal end, there is a large triangular pit with sharply raised borders marking the point of contact with the lower part of metatarsal I. The distal end is constricted, the smooth articular surface extending farther up on the posterior than on the anterior side, in sharp contrast to the condition found in metatarsal III. A deep longitudinal notch on the posterior side divides the articular area into two distinct narrow condyles, of which the median or inner one is the smaller.

The flattened proximal end of the third metatarsal, when observed from above, is trapezoidal in outline, the outer longest leg being strongly concave. Proximally, it is concavely expanded antero-posteriorly, but there is no transverse enlargement. Anteriorly, the shaft is flat, bounded laterally by sharp, angular edges. In cross section, it is subtriangular along its entire length, herein differing from the second metatarsal, the cross section of which varies from rectangular above to subround below. An elongate muscle scar occurs on the posterior side 130 mm. from the distal end. The distal end itself is convex antero-posteriorly and concave transversely, resulting in the development of two flat condylar surfaces which are noticeable even on the anterior side. Posteriorly, with the exception of the two small lateral condylar ridges, the bone is only slightly developed.

Distally, both bones exhibit the characteristic lateral pits, of which the external one is in each instance the larger.

The first phalanx of the third digit is a moderately robust bone approximately one-third as long as metatarsal III. It is expanded at both ends and constricted in the center. In lateral aspect, it is bowed slightly upward. The superior surface is gently rounded transversely, while that below is flat to moderately concave. The proximal end is deeply concave vertically and gently concave transversely. Its margin is sharp-edged and slightly higher in the center above than on either side as a result of the presence of a low, rounded, vertical, median keel in the upper one-third of the articular surface. Ventrally, there are two strong longitudinal ridges separated by a broad, sub-triangular, roughened concavity. These lateral ridges disappear at about midlength on the ventral side.

The distal end is pronouncedly convex vertically and moderately concave in the transverse direction. The smooth articular surface is produced farther anteriorly above than below. Just above the superior termination of this surface, a large transverse excavation gives a depressed appearance to the distal one-third of the bone. The two characteristic lateral pits are well developed, the one opposite digit II being subround in outline while the opposite deeper one is roughly triangular.

MEASUREMENTS OF THE HIND LIMB AND FOOT (in mm.)

	Type	Paratype
Femur		
Greatest transverse diameter of proximal end	-----	251
Greatest transverse diameter of distal end	216	-----
Length	1153*	-----

Tibia		
Least transverse diameter of shaft	94	......
Least antero-posterior diameter of shaft	73	......
Transverse diameter of distal end	221	245
Length	865*	958*
Fibula		
Width of distal end	58	......
Width of shaft and midlength	40	......
Length	801	......
Metatarsal II		
Transverse diameter of proximal end	63	......
Transverse diameter of distal end	86	......
Antero-posterior diameter of proximal end	108	......
Length	416	......
Metatarsal III		
Transverse diameter of proximal end	65	......
Least transverse diameter of shaft	44	......
Transverse diameter of distal end	100	......
Antero-posterior diameter of proximal end	125	......
Length	445	......
Phalanx III (1)		
Transverse diameter of proximal end	97	......
Transverse diameter distal end	83	......
Length	145	......

* Estimated.

OBSERVATIONS ON THE TAXONOMY OF ALTISPINAX

It is not within the scope of the present study to give a recapitulation of the taxonomic situation with respect to the carnivorous Saurischia; but a brief history of the Wealden genus *Altispinax* is considered desirable inasmuch as certain serious questions may be raised as to the actual composition of the type material representing this very inadequately known form, reference to which has been necessary throughout the present paper.

Dames (1884) described an isolated carnosaur tooth from the lower Wealden of northwestern Germany under the name, *Megalosaurus dunkeri.* Subsequently, Lydekker associated a large number of specimens with *M. dunkeri;* his evidence, however, appears far short of conclusive. Lydekker (1890) described a peculiar metatarsus and identified it with *M. dunkeri* saying:

> Now the type tooth of *M. dunkeri* is of comparatively large size and was obtained from the lower division of the Hastings beds, which must be equivalent either to the Wadhurst Clay or the underlying Ashdowns; . . . The Hollington metatarsus agreeing, therefore, in relative size with the type tooth and coming from approximately the same geologic horizon, there is every probability that it belongs to the same species, to which I accordingly propose to refer it.

The writers cannot accept this association, which was based essentially upon the relative size of two anatomically unrelated elements. It is widely recognized that the relative size of individual and homologous skeletal elements cannot be employed as a criterion for generic and specific identification in the large saurischian reptiles. The conclusion of Lydekker becomes even more untenable when it is realized that the size of carnosaurian teeth may vary greatly within the dental series of a single individual. In view of the above statement, the correlative geologic horizons seem to be of no great importance in the present instance inasmuch as the two locations are widely separated.

Von Huene (1926), however, apparently considers such an association as valid. He states:

> Bones referred to this species by Lydekker are not rare. . . . If No. 74 (three articulated medial dorsal vertebrae with extremely high neural processes) as seems to be the case—also belongs here, the species possesses enormously high neural spines in the dorsal vertebrae corresponding to four vertebral lengths. . . . But here, in fact, it is very remarkable for a carnosaurian and if it were confirmed that such dorsal vertebrae indeed belong to *Megalosaurus dunkeri* it would be necessary to put it into an own genus for which the name *Altispinax* n. gen. could be reserved.

Von Huene then concludes:

> The skeletal remains according to Lydekker, belonging with the teeth of *Megalosaurus dunkeri* (Dames) from the Lower Wealden are so different from *Megalosaurus* that they do not fit into the genus. Dorsal vertebrae with very high neural processes apparently belong together with these, and on this assumption the genus is called *Altispinax*. Probably the species *Oweni* (Lydekker) from the Upper Wealden belongs also there.

Von Huene is nowhere explicit as to just which material he considers the type of the genus *Altispinax,* nor does he state whether the various specimens referred to that genus were found in sufficient proximity to render their actual association acceptable. From the various statements concerning the material, however, it appears to the writers that the specimens which have been incorporated in the type material were, for the most part, found at different times and in more or less widely separated localities and that very little association actually existed between them. Furthermore, it is not clear how much duplication of the individual elements has occurred. Consequently, when von Huene states that "Dorsal vertebrae with very high neural processes apparently belong together with these and on this assumption the genus is called *Altispinax,*" apparently the vertebrae under consideration should be considered as constituting the type; and the association of other elements with them should be considered as problematical until such time as later discoveries may prove the validity of the association.

For the above reasons, therefore, allusion to other bones of *Altispinax* has been avoided in the present paper.

THE RELATIONSHIPS OF ACROCANTHOSAURUS

The carnosaurian affinity of *Acrocanthosaurus atokensis* is manifest in every known element of the skeleton. The problem of family relationship, however, has been greatly complicated from the very outset of the present study because of the inadequacy of comparative material. Although a considerable portion of the skeleton is known and a reasonably clear conception of the osteology can be gained from these remains, the more important details of structure from the taxonomic viewpoint have not been preserved.

During the past fifty years, certain definite conclusions have been reached concerning criteria of family importance among the Carnosauria. Comparison with these various criteria has been somewhat limited insofar as much of the present material is not of diagnostic value.

Acrocanthosaurus is excluded from the Deinodontidae by the relative elongation and pronounced opisthocoelous character of the cervical and anterior dorsal vertebrae, the relatively heavier construction of the pelvic elements, and the subequal proportions of the metatarsals in that genus.

The pronounced opisthocoelous character and great elongation of the dorsal vertebrae, together with the peculiar costal articulation in *Spinosaurus aegyptiacus* Stromer, remain unique among the large carnivorous saurischians. Consequently, the slight resemblance of the present form to the Spinosauridae, occasioned by the tendency toward elongation of the neural spines, is considered unimportant.

Comparison with the Megalosauridae of Europe and the Antrodemidae of North America has proved especially difficult owing to the similarity of the two groups. The association of *Acrocanthosaurus* with either of these families if, in fact, two separate families do exist, must be considered problematical since that genus presents many features common to both.

Certain characteristics of the Antrodemidae, however, find the closest analogy in the present form and differ accordingly from those exhibited by the European group. Principal among these are the construction of the skull, the general proportions of the vertebrae, and the broadly expanded pubic "foot,"* the straight elongate shaft of the ischium, and the presence of an anterior upward projection in the anterior chevrons. These features, together with the geographic consideration, seem sufficiently important at present to justify the incorporation of *Acrocanthosaurus* into the family Antrodemidae.

The peculiar development of the neural spines is apparently of little systematic importance and *Acrocanthosaurus* may be considered an example of parallel development along the lines indicated by *Megalosaurus parkeri* and *Altispinax*.

CONCLUSIONS

1. The present form, described under the name of *Acrocanthosaurus atokensis* in allusion to the elongate neural spines, represents a large and aberrant carnivorous saurischian at present peculiar to the Trinity Cretaceous of Atoka County, Oklahoma.

2. The genus, as here described, clearly falls within the range of the forms encompassed by the Carnosauria but is generically and specifically distant from all known members of that group.

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* The presence or absence of the broadly expanded pubic symphysis in the true megalosaurs has not been definitely ascertained, but presently known specimens apparently lack any such enlargement. *Megalosaurus parkeri* does, however, exhibit some enlargement, but does not approach the extreme condition seen in *Antrodemus* or the later deinodonts.

3. Family affinities are not clear, but on the basis of arguments of geologic and geographic distribution, the genus has been incorporated into the Family Antrodemidae Marsh.

4. Massive and elongate neural spines, which are apparently characteristic of the genus, are considered as a rapidly acquired characteristic. Such spines were imbedded in a thick and high dorsal ridge of muscle, but the reasons for such development are obscure.

5. The validity of certain European material ascribed to *Megalosaurus dunkeri* Dames is questionable.

6. *Altispanax dunkeri* (Dames) is a valid form only when the type material is understood to include only the three dorsal vertebrae described by Owen as *Megalosaurus bucklandi* Meyer.

7. *Acrocanthosaurus atokensis* is considered as a case of parallel development along the lines indicated by the older European forms *Megalosaurus parkeri* Huene and *Altispinax dunkeri* (Dames), and the latter are not necessarily ancestral to it.

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Plate 1.—*Acrocanthosaurus atokensis* gen. et sp. nov. Cranium. M.U.O. 8-O-S9. Front view. Fr—frontal, Pa—parietal, Poc—paroccipital process, Prot—prootic, Bsp—basispenoid, Bpt—basipterygoid process of the basisphenoid, Pas-parasphenoid, Psp?—supposed presphenoid, Eth?—supposed ethmoid, F.O.—fenestra ovalis, C.I.—entrance of internal carotid, Pi Fos—pituitary fossa, I-V—exits of cranial nerves i-v. About two-fifths natural size.

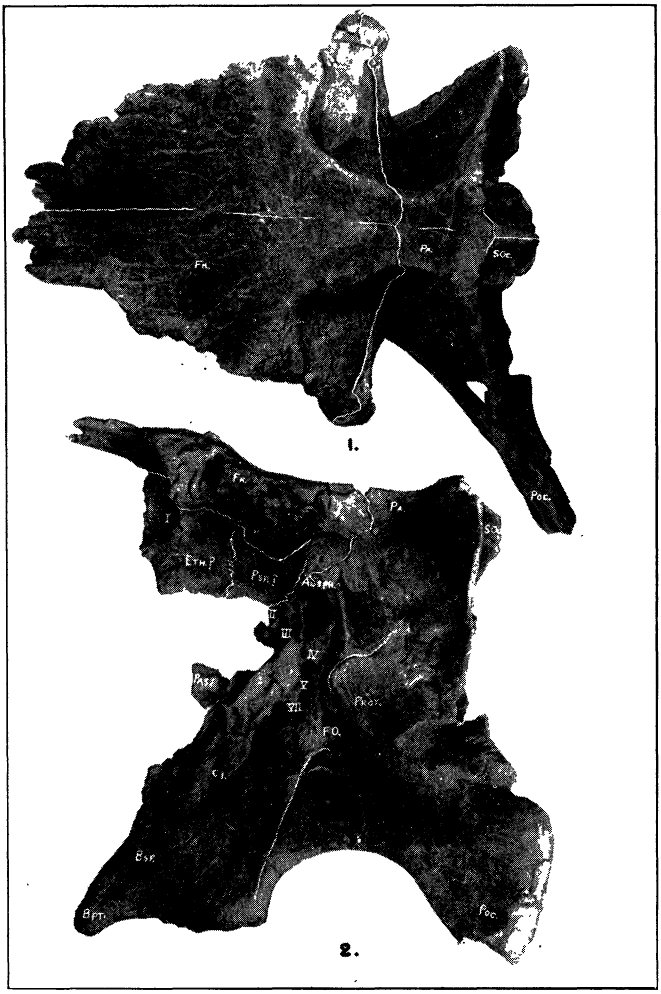

Plate 2 . Figs. 1, 2. *Acrocanthosaurus atokensis* gen. et sp. nov. Cranium. M. U. O. 8 O-S9.—1. Superior view; Fr—frontal, Pa—parietal, Soc—supraoccipital, Poc—paroccipital process; 2. Lateral view; Prot—prootic, Psp?—supposed presphenoid, Eth?—supposed ethmoid, Bsp—basisphenoid, Bpt—basipterygoid process of the basisphenoid, Pas—parasphenoid, F.O.—fenestra ovalis, C.I.—lower entrance of internal carotid, I-VII—exits of cranial nerves i-vii. Both figures about two-fifths natural size.

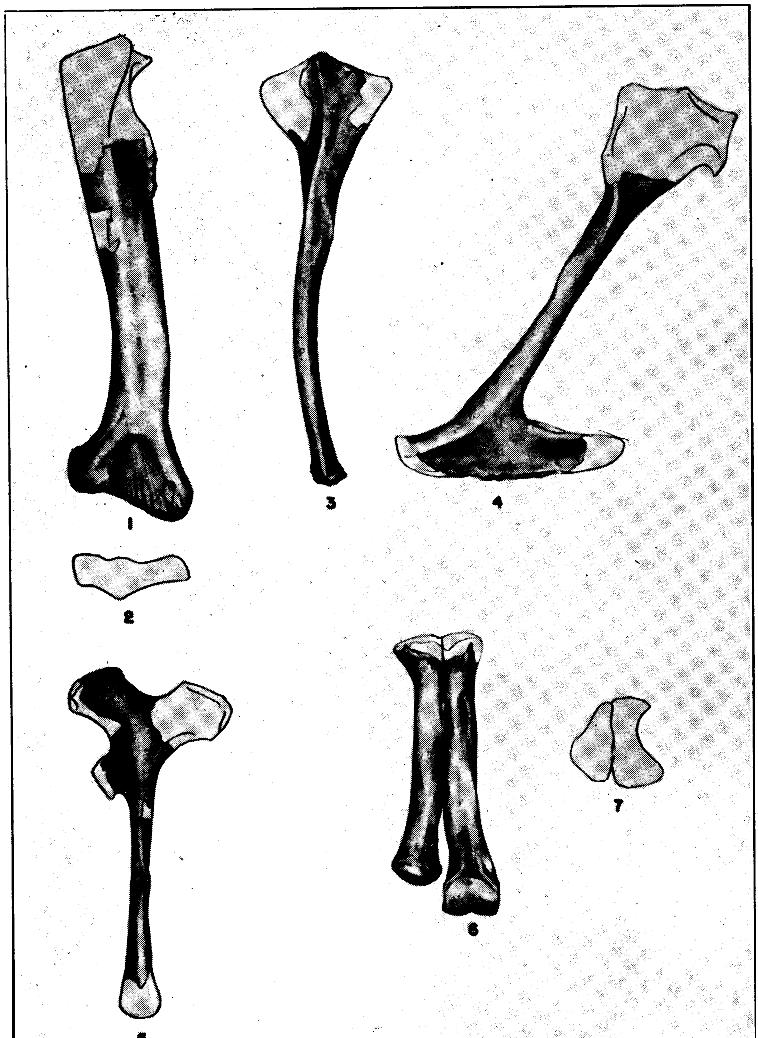

Plate 3. Figs. 1-7. *Acrocanthosaurus atokensis* gen. et sp. nov.—1. Left tibia, M. U. O. 8-O-S9. Anterior view; 2. Outline of distal end of left tibia, M. U. O. 8-O-S9; 3. Right fibula, M. U. O. 8-O-S9. Lateral view; 4. Left pubis, M. U. O. 8-O-S8. Lateral view; 5. Left ischium, M. U. O. 8-O-S8. Lateral view; 6. Left metatarsals II and III, M. U. O. 8-O-S8. Anterior view; 7. Outline of proximal articular surfaces of metatarsals II and III, M. U. O. 8-O-S8. All figures about one-tenth natural size.

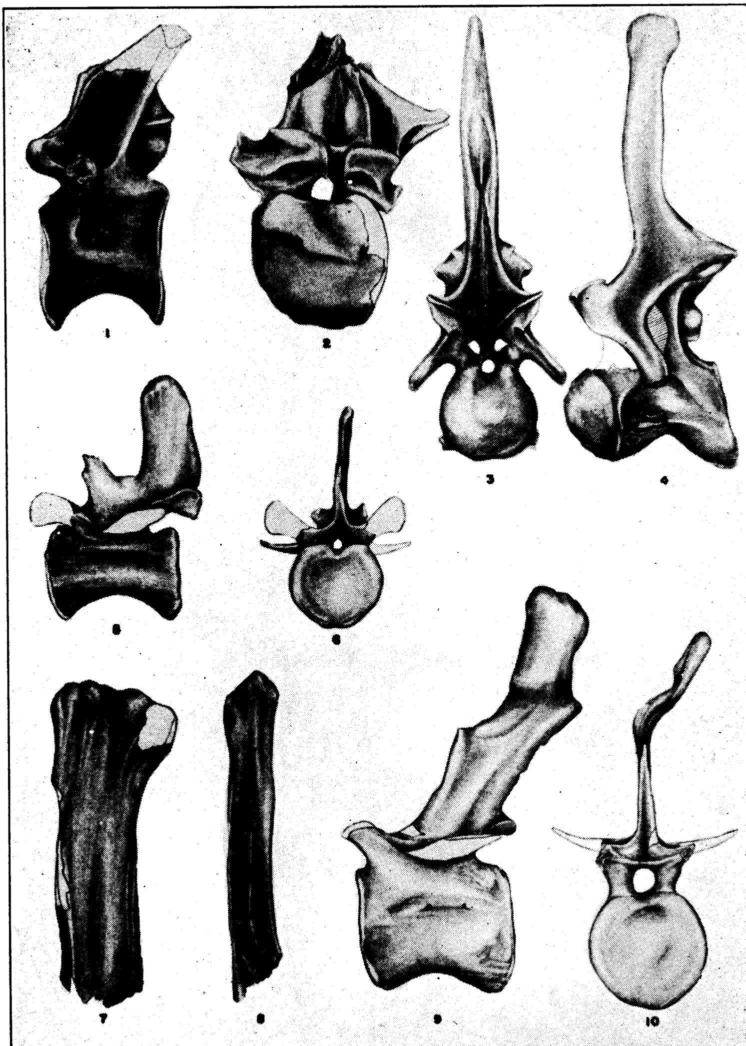

Plate 4. Figs. 1-10. *Acroconthosaurus atokensis* gen. et sp. nov. Vertebrae.—1. Sixth dorsal, M. U. O. 8-O-S9. Lateral view; 2. Same. Anterior view; 3. Ninth cervical, M. U. O. 8-O-S9. Anterior view; 4. Same. Lateral view; 5. Medial caudal, M. U. O. 8-O-S8. Lateral view; 6. Same. Anterior view; 7. Dorsal spine, M. U. O. 8-O-S9. Lateral view; 8. Same. Anterior view; 9. Eleventh caudal, M. U. O. 8-O-S8. Lateral view; 10. Same. Anterior view. All figures about one-eighth natural size.