

## LARGE, EARLY CRETACEOUS THEROPODS IN NORTH AMERICA

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**ABSTRACT:** *Acrocanthosaurus*, from the Trinity Group of Oklahoma and Texas, remains the only adequately known large theropod from the Lower Cretaceous of North America, though large theropod bones have been recovered from the Cloverly, Arundel, and Cedar Mountain Formations. All the known clearly diagnostic elements (except some teeth) from these units pertain to taxa that are not congeneric with *Acrocanthosaurus*. The Arundel, Cloverly, and Cedar Mountain formations appear to be, at least in part, approximately contemporaneous with Trinity Group sediments. As a result, *Acrocanthosaurus* was not the only large theropod inhabiting North America during the Early Cretaceous.

### INTRODUCTION

In contrast with small theropod taxa (e.g., *Deinonychus* [Ostrom, 1969] and *Microvenator* [Ostrom, 1970]), large theropods in the Lower Cretaceous of North America remain poorly known. This situation contrasts sharply with those of other dinosaur-bearing formations on the continent; for example, in the Upper Jurassic Morrison Formation, large theropods (e.g., *Allosaurus* and *Ceratosaurus*) are represented by more numerous and more complete specimens than contemporaneous small theropods (e.g., *Ornitholestes*, *Coelurus*, and *Elaphrosaurus*).

To date, the only large theropod from the Lower Cretaceous of North America known from relatively complete, diagnostic material is *Acrocanthosaurus atokensis*. The holotype and paratype specimens of this taxon are fragmentary skeletons from the Antlers Formation of Oklahoma (Stovall and Langston, 1950); the taxon has recently been redescribed based on a more complete skeleton (Harris, 1997, 1998). The comparative, if not actual, completeness of material of *Acrocanthosaurus* has led several authors (e.g., Pittman, 1989; DeCourten, 1991) to attribute isolated large theropod elements from Lower Cretaceous sediments in North America to *Acrocanthosaurus* or a similar taxon without identifying in those elements any autapomorphies of the taxon. The tacit assumption is that *Acrocanthosaurus* is the only large theropod present in the Lower Cretaceous of North America. However, material from other large theropods does exist, and can be shown to belong to taxa other than *Acrocanthosaurus*.

Abbreviations used: CEU = College of Eastern Utah, Price; FWMSH = Ft. Worth Museum of Science and History, Ft. Worth; OMNH = Oklahoma Museum of Natural History; SMU = Southern Methodist University, Dallas; USNM = United States National Museum, Smithsonian Institution, Washington, D.C.; UUVP = University of Utah, Salt Lake City; YPM = Yale Peabody Museum, New Haven

### ARUNDEL FORMATION

The first Early Cretaceous large theropod material described from North America was from the Arundel Formation (Potomac Group) of Maryland. Marsh (1888) based the species *Allosaurus medius* on teeth, an astragalus, and a phalanx. Lull (1911) attributed vertebrae to the taxon; Lull et al. (1911) specified four vertebrae (a ?mid- or ?caudal dorsal, a proximal caudal, and two distal caudals) and two phalanges, all from the same locality, as the original material. Lull et al. (1911) referred all the material, except a single tooth, attributed to the taxon by Marsh (1888) to the ornithomimid *Dryosaurus*. (The material was shown to be

ornithomimosaurian by Gilmore [1920, 1921], and the phalanges were referred to the genus *Archaeornithomimus* by Russell [1972; q.v. Kranz, 1989].) Having removed all elements except the tooth from *A. medius*, Lull et al. (1911) then attributed a caudal dorsal, a proximal caudal, and two distal caudal vertebrae as well as two pedal phalanges to the taxon. Gilmore (1920, 1921) noted that the two distal caudals belong to an ornithomimosaurian and again asserted that only the tooth (USNM 4972) could be typical of *A. medius*. Gilmore (1921) removed the tooth from the genus *Allosaurus* and referred to it as ?*Dryptosaurus medius*. The tooth lacks an adequate description, and its status is indeterminate.

Lull (1911) described a second large Arundel theropod, *Creosaurus potens*, on the basis of a vertebral centrum (USNM 3049) larger than those assigned to *A. medius*. Lull et al. (1911) described it as a caudal dorsal vertebra, but it was shown by Gilmore (1921) to be a proximal caudal. Gilmore (1921) noted that the genus *Creosaurus* was congeneric with *Allosaurus*, and that the isolated Arundel centrum was more similar to the Late Cretaceous theropod *Dryptosaurus aquilunguis* (Cope, 1866; Marsh, 1877; Carpenter et al., 1997), so he called the Arundel form ?*Dryptosaurus potens*. The Arundel centrum lacks any medial constriction and possesses a single, strong ventral keel (Gilmore, 1921). In contrast, caudals of *Acrocanthosaurus* have arched ventral margins, and where keeled, have a low, double keel (Harris, 1997, 1998). The Arundel centrum lacks the rudimentary pleurocoelous fossae present on the proximal caudal centra of *Acrocanthosaurus* as well (Fig. 1). Thus, there is a large theropod present in the North American Early Cretaceous that is distinct from *Acrocanthosaurus*. It remains unknown whether or not this caudal vertebra belongs to the same taxon as the tooth of ?*Dryptosaurus medius*. Weishampel and Young (1996: 132) consider all the non-ornithomimosaur theropod material from the Arundel Formation indeterminate, but it is at least clear that the caudal vertebra is not congeneric with *Acrocanthosaurus*.

Large, isolated theropod teeth from the Arundel are reportedly (T. Lipka, personal communication, 1997) virtually identical to those of *Acrocanthosaurus* described by Harris (1997, 1998), so this genus may be present in the Arundel fauna, as well.

### CLOVERLY FORMATION

Ostrom (1970: 69–70, fig. 6) described a dorsal vertebra (YPM 5285) belonging to an "indeterminate theropod" from the Cloverly Formation of Montana. This specimen is markedly different from dorsals of *Acrocanthosaurus* described by Harris (1997, 1998). The vertebra is not opisthocelous, as are the cranial dorsals of

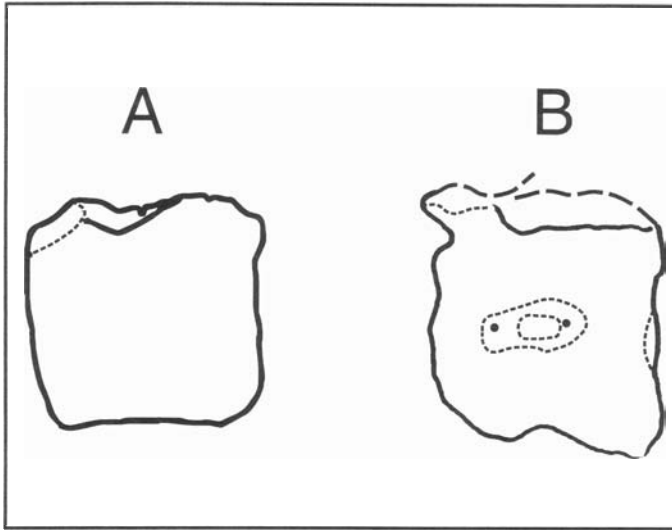


FIGURE 1. A, Caudal vertebral centrum, USNM 3049, referred to *?Dryptosaurus potens*, from the Arundel Formation of Maryland (after Gilmore, 1921). Centrum length = 14 cm. B, Eighth caudal vertebral centrum, SMU 74646/FWMSH 93B-9 1-12, of *Acrocanthosaurus* (from Harris, 1997). Centrum length = 13.5 cm. Not to scale.

*Acrocanthosaurus*. While the Cloverly vertebra's transverse processes do have a dorsocaudal angulation, it is not as strong as in *Acrocanthosaurus*. Its centrum lacks pleurocoels, and the transverse process is not invaded by the large, deep fossae seen in *Acrocanthosaurus* (Harris, 1997, 1998). The pre- and postzygapophyses of the Cloverly form are small and simple, unlike the large, arched facets of *Acrocanthosaurus*. The neural spine is not elongate, and expands craniocaudally towards its summit, both unlike *Acrocanthosaurus* (Fig. 2). Overall, the Cloverly vertebra appears to have originated with a theropod more primitive than *Acrocanthosaurus*. As noted by Ostrom (1970), the Cloverly dorsal cannot be compared with the proximal caudal vertebra of *?Dryptosaurus potens* from the Arundel to assess congenericity. If it represents a distinct taxon, then there is a second large, non-*Acrocanthosaurus* theropod present in the Early Cretaceous of North America.

#### CEDAR MOUNTAIN FORMATION

DeCourten (1991: fig. 5) illustrates a tooth (UUVP 904) from the Long Walk Quarry in the Cedar Mountain Formation (Ruby Ranch Member *per* Kirkland et al., 1997) of Utah attributed to *Acrocanthosaurus* or a similar taxon. Kirkland and Parrish (1995) and Kirkland et al. (1997) state their belief that the tooth morphology is distinct from *Acrocanthosaurus*. Examination of this specimen indicates that it differs from the *Acrocanthosaurus* tooth described by Harris (1997, 1998) in possessing approximately 1 denticle per mm, as opposed to 2 per mm in the Trinity taxon's tooth. However, precise measurements could not be taken, and examination of the specimen was impaired by incomplete preparation between the denticles. Furthermore, without description of complete tooth-bearing skull elements for *Acrocanthosaurus*, it is unclear if there is differentiation between teeth at various positions in the mouth: the denticle size difference between the Cedar Mountain and Trinity teeth may simply be an artifact of heterodonty.

Kirkland et al. (1997) note the presence of an large theropod

ilium, also from the Long Walk Quarry. The association of the ilium in the same quarry as the teeth may indicate that they originated from the same taxon, if not the same individual. As no ilium of *Acrocanthosaurus* has yet been described, it is impossible to determine if the specimen represents the Trinity taxon, the taxon represented in the quarry by the coarsely-serrated teeth, or a different large theropod. If the ilium and the teeth belong to the same taxon, then it remains distinct from *Acrocanthosaurus*. The table provided by Kirkland et al. (1997, p. 79, table 2) states that "*cf. Acrocanthosaurus* sp." is present in the Ruby Ranch fauna; this is in reference to an isolated tooth (CEU 5107) with very fine serrations from the Cedar Mountain Formation near the Cleveland-Lloyd Dinosaur Quarry (J. Kirkland, personal comm., 1998). The table also lists a "new large theropod" in the Ruby Ranch fauna, in reference to the taxon represented by the coarsely-serrated teeth.

#### AGES OF LOWER CRETACEOUS FORMATIONS OF NORTH AMERICA

*Acrocanthosaurus* is known from the Twin Mountains Formation of Texas (Harris, 1997, 1998) and the Antlers Formation of Oklahoma (Stovall and Langston, 1950). The Aptian-Albian boundary, dated to  $112 \pm 0.1$  Ma by Obradovich (1994) and

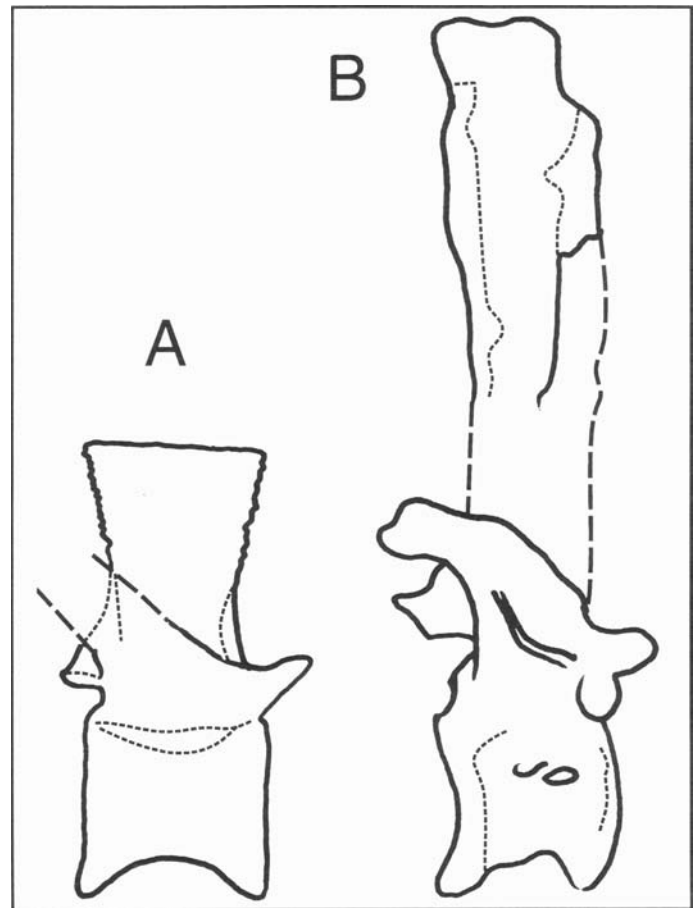


FIGURE 2. A, Dorsal vertebra, YPM 5285, of a large, unidentified theropod from the Cloverly Formation of Montana (after Ostrom, 1970). Centrum length = 9.5 cm. B, Ninth dorsal vertebra, SMU 74646/FWMSH 93B-9 A1-2-14 (centrum) and 2A-3 (neural spine; height based on OMNH 8-0-S9) of *Acrocanthosaurus* (from Harris, 1997). Centrum length = 13.5 cm. Drawings not to scale.

Gradstein et al. (1994, 1995), can be identified, based in part on ammonite biostratigraphy (Young, 1986), in the Glen Rose Limestone that overlies the Twin Mountains Formation in Texas (Jacobs et al., 1991; Winkler et al., 1995). A late Aptian-early Albian age for the group, and a late Aptian age for the Twin Mountains Formation in particular, is supported by  $\delta^{13}\text{C}$  correlation data (Rennison, 1996; see also Jacobs and Winkler, in press).

The age of the Arundel Formation has been listed as late Aptian or early Albian (Kranz, 1989, 1996); this age, for at least a portion of the dinosaur-bearing strata, is supported by palynostratigraphy (Robbins, 1991; Doyle, 1992). Thus, the large theropod represented by the caudal called *?Dryptosaurus potens*, as well as the tooth of *?Dryptosaurus medius*, may be approximately contemporaneous with *Acrocanthosaurus*.

Ostrom (1970) used vertebrate biostratigraphy to date the Cloverly Formation to the late Aptian-early Albian. Cloverly and Trinity Group sediments share the dinosaur genera *Deinonychus* (Cifelli et al., 1997b) and *Tenontosaurus* (Winkler et al., 1997), the chelonian *Naomichelys* (Ostrom, 1970), and several related mammals (Jacobs et al., 1991; Cifelli, 1993); however, some of the shared taxa differ at the species level (Cifelli et al., 1997b; Winkler et al., 1997), and *Naomichelys* is of dubious biostratigraphic utility due to its long temporal distribution (Cifelli et al., 1997a). Comparison of the mammalian faunas shows that the Cloverly fauna may be contemporaneous or slightly younger than the Trinity (Jacobs et al., 1991; Jacobs and Winkler, in press). Fission-track dating of zircons from volcanic tuffs in the Cloverly have yielded ages as old as the Valanginian (~ 137-132 Ma: Gradstein et al., 1995) at its base to late Aptian-middle Albian and younger at the top (Chen and Lubin, 1997). Ostrom (1970) finds many Cloverly taxa to have a relatively wide stratigraphic distribution, and the range of the poorly-known large theropod represented by the dorsal vertebra is unknown: it could be somewhat older, contemporaneous, or slightly younger than *Acrocanthosaurus*.

The Cedar Mountain Formation records a large portion of the Early Cretaceous and at least part of it, the Ruby Ranch Member, appears to be correlative with the Trinity Group based on faunal similarities (Kirkland, 1996; Kirkland et al., 1997; Cifelli et al., 1997a). Although the absolute age of the Ruby Ranch Member is not yet available for comparison with the well-constrained age of the Trinity fauna (Jacobs and Winkler, in press), the faunal similarities (Kirkland et al., 1997) likely indicate a similar age.

## CONCLUSIONS

Although diagnostic material of *Acrocanthosaurus atokensis* has not yet been identified from sediments outside of the Trinity Group, large theropods are found in other Lower Cretaceous rocks in North America. Described material, including a proximal caudal vertebral centrum from the Arundel Formation of Maryland (*?Dryptosaurus potens*) and a caudal dorsal vertebra from the Cloverly Formation of Montana, are clearly distinct from *Acrocanthosaurus*. A tooth from the Ruby Ranch Member of the Cedar Mountain Formation of Utah also appears distinct. Therefore, there is at least one, and possibly as many as three, large theropods in addition to *Acrocanthosaurus* present in the Lower Cretaceous of North America.

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