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THE LATE CRETACEOUS TUCSON MOUNTAINS DINOSAUR

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Abstract—Historically, the "Tucson Mountains dinosaur" has been considered an Early Cretaceous iguanodont from a megabreccia block of the Amole Arkose in the Tucson Mountains caldera of southern Arizona. We demonstrate here that it is instead a large hadrosaur represented by an incomplete left hindlimb, including an incomplete ilium, proximal and distal femur, a distal tibia, a proximal metatarsal and unidentifiable bone elements. This specimen is diagnostically a hadrosaur because it is very large and has distal femoral condyles greatly expanded caudally and a very deep intercondylar groove on the distal femur. In the American West, hadrosaurs are restricted to strata of Late Cretaceous age, and large hadrosaurs typically indicate a Campanian or Maastrichtian age.

The collecting locality of the hadrosaur lies ~550 m NNW of Gates Pass in ground exposing lenticular bodies of intracaldera megabreccia that interfinger complexly with Cat Mountain Tuff, the compound cooling unit of welded ash-flow tuff that forms the fill of the Tucson Mountains caldera. Megabreccia bodies were formed by landslides that slid into the caldera from its walls during eruption, and are blocks of extracaldera rocks encased in partially welded intracaldera tuff. The Cat Mountain Tuff has yielded multiple K-Ar (feldspar) ages of 68-72 Ma, and a single $^{40}Ar/^{39}Ar$ age (biotite) of 73.1 Ma. Approximately 8 km WNW of the dinosaur locality, the Tuff of Confidence Peak (~73 Ma), which was erupted from the Silver Bell caldera 30 km NW of the Tucson Mountains caldera, is interbedded with upper horizons of the Amole Arkose as exposed just outside the Tucson Mountains caldera. The stratigraphic relationship of the Tuff of Confidence Peak to the Amole Arkose is evidence that the latter includes strata at least as young as Campanian in age, even though older parts of the Amole Arkose are evidently correlative with Lower Cretaceous Bisbee Group. The sandstone matrix of the hadrosaur fossil thus is a block derived from an Upper Cretaceous horizon in the upper Amole Arkose.

Keywords: Late Cretaceous, hadrosaur, Tucson Mountains, Arizona, Amole Arkose, dinosaur

INTRODUCTION

Cretaceous strata preserved in southeastern Arizona were deposited in two different tectonic regimes. The older Cretaceous rocks belong to the Bisbee Group and were deposited in rift basins that were part of a large extensional tectonic region that encompassed parts of northern Mexico (Sonora and Chihuahua), southwestern New Mexico and southeastern Arizona; the younger Cretaceous rocks were deposited during compressional tectonism of the Laramide orogeny (Dickinson and Lawton, 2001, and references cited therein). Between the Bisbee Group and Laramide Cretaceous deposits there is a regional unconformity during which little or no sediment accumulated in southeastern Arizona (e.g., Hayes, 1970). The age of Bisbee Group strata in southeastern Arizona ranges from Jurassic to late Albian, and perhaps locally into the Cenomanian; Laramide strata in southeastern Arizona are Campanian-Paleogene in age (e.g., Hayes, 1970; Dickinson and Lawton, 2001; Heckert et al., 2003).

Dinosaur fossils from southeastern Arizona thus are either Early Cretaceous (mostly Albian) in age or Late Cretaceous (Campanian) (Heckert et al., 2003). Here, we document the Tucson Mountains dinosaur (Figs. 1-2), a specimen whose age relationships have long been equivocal. In this paper, UALP = University of Arizona Laboratory of Paleontology, Department of Geosciences, Tucson.

LOCALITY

The collecting locality (GPS coordinates 32° 13.585′ N, 111° 6.231′ W; Fig. 1) of the Tucson Mountains dinosaur (UALP local-

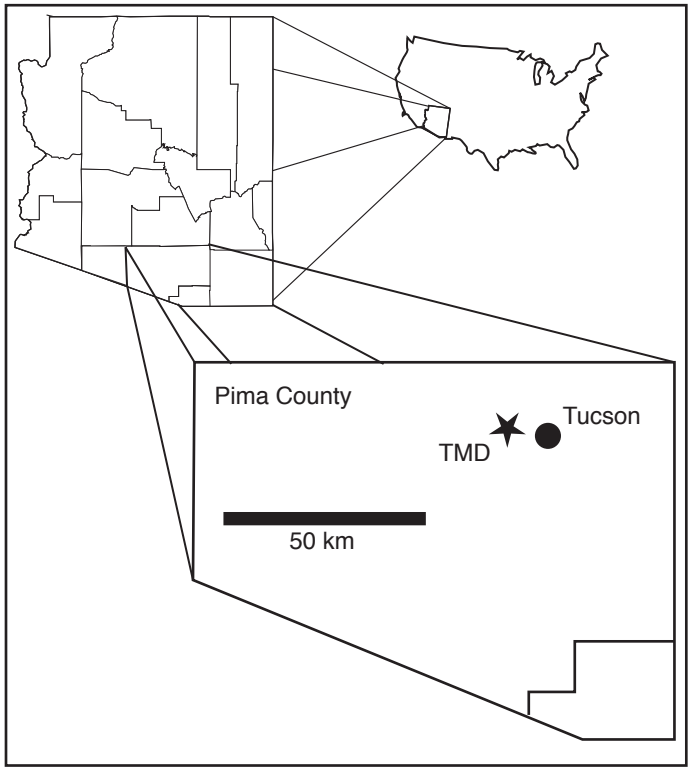

FIGURE 1. Index map of Arizona showing location (star) of the Tucson Mountains dinosaur locality (TMD) in southern Arizona.

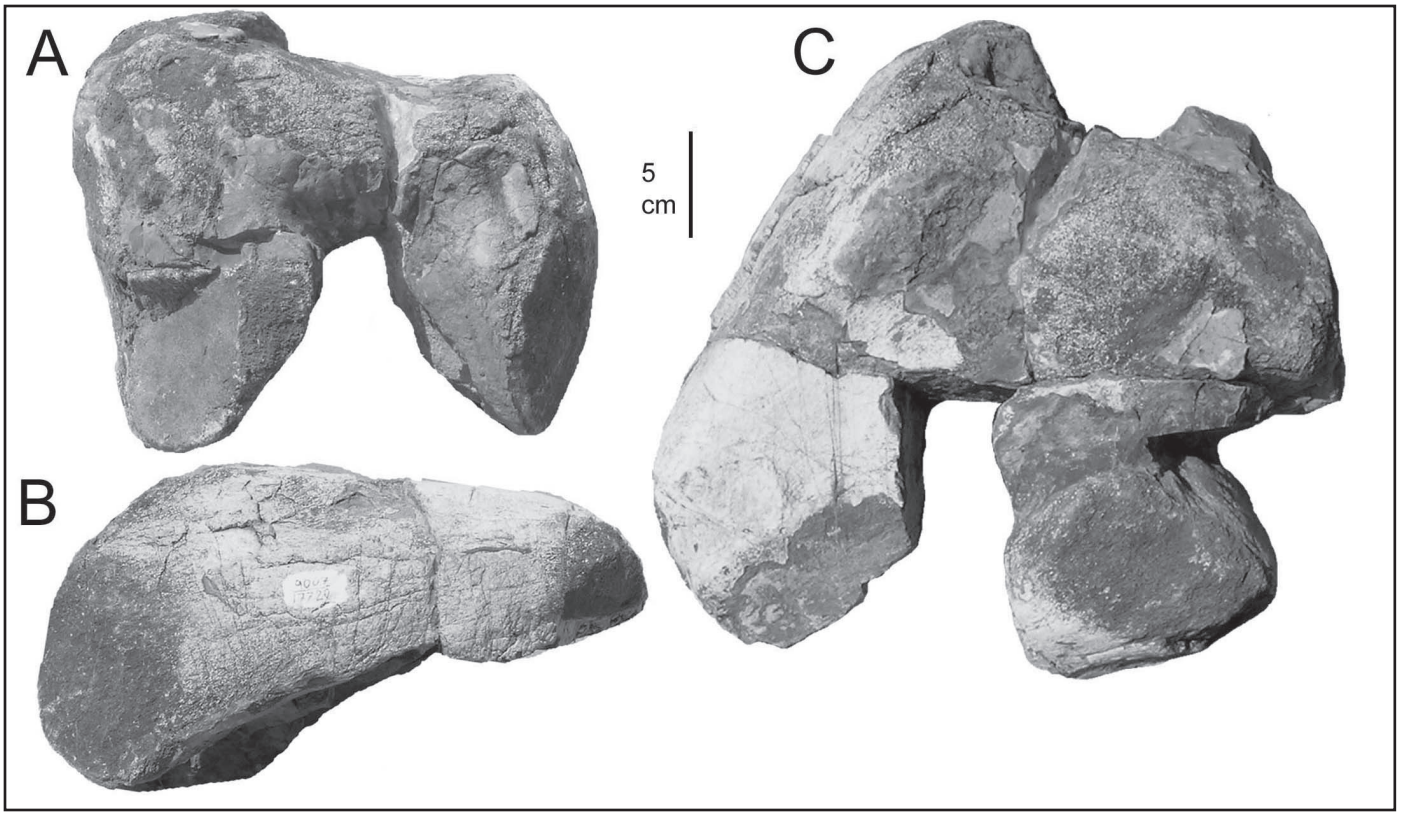

FIGURE 2. Distal end of left femur of the Tucson Mountains dinosaur, UALP 9007, in **A**, distal, **B**, lateral, and **C**, cranial views.

ity 17720) lies ~550 m NNW of Gates Pass in ground exposing lenticular bodies of intracaldera megabreccia that interfinger complexly with the Cat Mountain Tuff, the compound cooling unit of welded ash-flow tuff that forms the fill of the tilted Tucson Mountains caldera (Lipman, 1993). Megabreccia bodies were formed by landslides that slid into the caldera from its walls during eruption, and are composed of blocks of extracaldera rocks encased in partially welded intracaldera tuff. The sandstone matrix of the dinosaur specimen apparently represents a block within megabreccia that was derived from sedimentary strata exposed on the wall of the caldera.

The Cat Mountain Tuff has yielded multiple K-Ar (feldspar) ages of 68-72 Ma, and a single $^{40}Ar/^{39}Ar$ age (biotite) of 73.1 Ma (Lipman, 1993). Approximately 8 km WNW of the dinosaur locality, the Tuff of Confidence Peak (~73 Ma), which was erupted from the Silver Bell caldera lying 30 km northwest of the Tucson Mountains caldera, is interbedded with upper horizons of the Amole Arkose as exposed just outside the Tucson Mountains caldera. Although available radioisotopic ages are not precise enough to distinguish the Tuff of Confidence Peak from Cat Mountain Tuff, the Tuff of Confidence Peak contains more abundant biotite and larger quartz phenocrysts, and is overlain by extracaldera outflow facies of Cat Mountain Tuff in the Silver Bell Mountains (Lipman, 1993).

DESCRIPTION AND IDENTIFICATION

The Tucson Mountains dinosaur is catalogued as UALP 9007. McCord and Tegowski (1996, p. 46) stated that it encompasses "two distal femora, proximal tibiae and fibulae, distal tibia and fibula, an astragalus, seven or more thoracic vertebrae, and portions of the ilium of an apparently articulated individual." However, our examination of the specimen only confirmed the presence of an incomplete ilium, proximal and distal femur (Fig. 2), a distal tibia, a proximal metatarsal and unidentifiable bone elements. The specimen is not prepared, fragmentary and distorted, and remains largely encased in matrix. However, diagnostic features are preserved in several elements, particularly the femur, which we describe in detail here.

The best preserved and most diagnostic element of the Tucson Mountains dinosaur is a distal left femur (Fig. 2), so we focus description and identification on this element. The distal left femur is exceptionally large. It is ~ 325 mm wide distally and ~ 312.5 mm long proximo-distally. This means it is essentially the same size as the hadrosaur femur from the Ojo Alamo Sandstone in New Mexico illustrated by Fassett and Lucas (2000, fig. 5), which indicates a total femur length for UALP 9007 of about 1300 mm. What is preserved of the femoral shaft is nearly straight and only widens slightly at the distal end. The distal condyles are not complete but prominent and rounded postero-distally. The medial condyle is larger than the lateral condyle, and the two condyles are separated anteriorly by a relatively shallow sulcus, but posteriorly by a much narrower and tubular sulcus. This posterior sulcus is the intercondylar groove, which in hadrosaurids usually is very deep, forming a cylindrical (tubular) passage for the extensor tendons.

The specimen is readily identified as a hadrosaur femur (cf. Lull and Wright, 1942, figs. 24, 50, pl. 6; Brett-Surman, 1972, pl. 7; Weishampel and Horner, 1990, p. 551-552, fig. 26.10; Fassett and Lucas, 2000, fig. 5), especially given the deep, nearly tubular intercondylar groove and large size. It is larger than any of the hadrosaur femora listed by Lull and Wright (1942, table 5) but smaller than the largest hadrosaur femur known (1650 mm long), that of *Shantungosaurus* from the Upper Cretaceous of China (Hu, 1973). Thus, UALP 9007 is much larger than femora of iguanodontids and *Tenontosaurus* (e.g., Ostrom, 1970; Galton and Jensen, 1979) and distinguished as well by the intercondylar groove on the distal femur, among other features. Indeed, UALP 9007 closely resembles an incomplete distal hadrosaur femur

from the Campanian Fort Crittenden Formation illustrated by Heckert et al. (2003, fig. 4), though the Tucson Mountains femur is larger. Other features of UALP 9007 conform to the morphology of a hadrosaurid. The Tucson Mountains dinosaur thus is a hadrosaur, but a more precise identification cannot be made of the incomplete, fragmentary fossil.

AGE

The significance of the Tucson Mountains dinosaur lies in its age. McCord and Tegowski (1996) considered the Tucson Mountains dinosaur to be of Aptian-Albian age, largely based on its derviation from the Amole Arkose, a stratigraphic unit normally assigned an Aptian-Albian age. Ratkevich (1997) termed it an iguanodont of Early Cretaceous age, an identification repeated by Weishampel et al. (2004, p. 555). However, identification of the Tucson Mountains dinosaur as a large hadrosaur is compelling evidence of a Late Cretaceous (most likely Campanian) age.

The stratigraphic relationship of the Tuff of Confidence Peak to the Amole Arkose is evidence that the latter unit includes strata at least as young as Campanian in age, even though older parts of the Amole Arkose are evidently correlative with Lower Cretaceous Bisbee Group (Risley, 1987). The sandstone matrix of the dinosaur specimen thus is a block derived from an Upper Cretaceous horizon in the upper Amole Arkose. Therefore, the Tucson Mountains dinosaur is a Late Cretaceous hadrosaur of probable Campanian age.

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