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Evidence for a *Tyrannosaurus rex* from southeastern Colorado

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Discovery

Dinosaur tooth and bone fragments were recovered from private property at an undisclosed locality in southeastern Colorado. The site is in an unnamed, transitional member of the uppermost Pierre Shale and is likely within the *Baculites eliasi* ammonite zone (N. Larson, pers. comm. 2007), making the site early Maastrichtian. This is the first record of dinosaur fossils from these strata.

Selected systematic paleontology

Order SAURISCHIA Seeley 1888
Family TYRANNOSAURIDAE Osborn 1905
Genus *TYRANNOSAURUS* Osborn 1905
cf. *T. REX* Osborn 1905

Referred specimens—TSJC 2008.1.1; TSJC 2008.1.2; TSJC 2008.1.3.

Description—Tooth: A tyrannosaurid tooth (TSJC 2008.1.1) most closely resembles the teeth of *"Nanotyrannus lancensis"* (or adolescent *T. rex*, Carr and Williamson 2004) based on crown shape and serration density (N. Larson, pers. comm. 2007). In straight-line measurement, the tooth is approximately 3.5 cm from tip to base. The serration density along the anterior carina is 12/cm, justifying the diagnosis as *T. rex* (Farlow et al. 1991). The tooth is slightly recurved, blunt, bears denticles along its anterior carina, and is broken at its base.

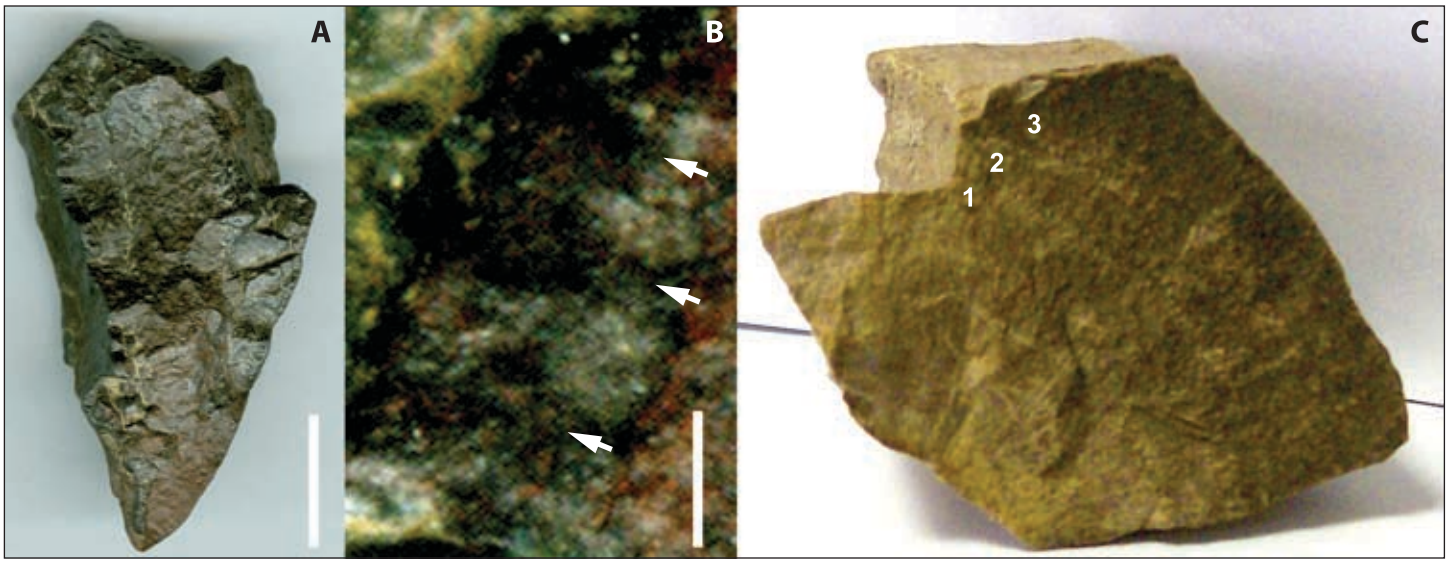
Femur: A limb bone fragment (TSJC 2008.1.2) is also tentatively identified as cf. *T. rex*. Theropod bones commonly exhibit onion-skin layering in cross section (K. Carpenter, pers. comm. 2007), and this bone seems to lack this feature, although the bone has distinct, differentiable layers. Whereas the bone itself may not be exclusively attributed to a theropod based on its gross histological properties alone, there are quantitative reasons supporting this diagnosis. First, the bone fragment is circular in cross section, and intersecting perpendicular bisectors of lines secant to its intact, periosteal surface suggest a radius of 90 ± 0.1 mm. As long bone circumference is used to estimate a live animal's weight (Anderson et al. 1985; Alexander 1989), a 90 mm radius corresponds to a biped weighing approximately 5.23 metric tons. In Maastrichtian time in western North America, this value is exclusive to *T. rex* as far as mass estimates based on long bone circumferences for bipeds are concerned (Alexander 1989; Horner et al. 2004). Second, as *T. rex* femora have circular cross sections at their midpoint (Farlow et al. 1995; Holtz 2004) and the published growth curve for *T. rex* is based on midshaft femoral measurements (Erickson et al. 2004), it is possible to quantitatively compare the published growth curve for *T. rex* with the growth pattern observed in this specimen. Measuring the midpoint of each growth line to an accuracy of ± 0.5 mm along a radial transect, *T. rex* annual growth markers are exceptionally good predictors for the growth lines observed in this bone ($\chi^2 = 1.44$, df = 6, p-value > 0.95). As *T. rex* is the only animal known to exhibit this characteristic pattern of growth (Erickson et al. 2004; Chinsamy-Turan 2005), this is believed to be a fairly powerful diagnostic test.

Significance—Estimated to be about 71 m.y. old based on the age of the *Baculites eliasi* ammonite zone, these fossils may be among the oldest known *T. rex* fossils (D. Wolberg, pers. comm. 2007).

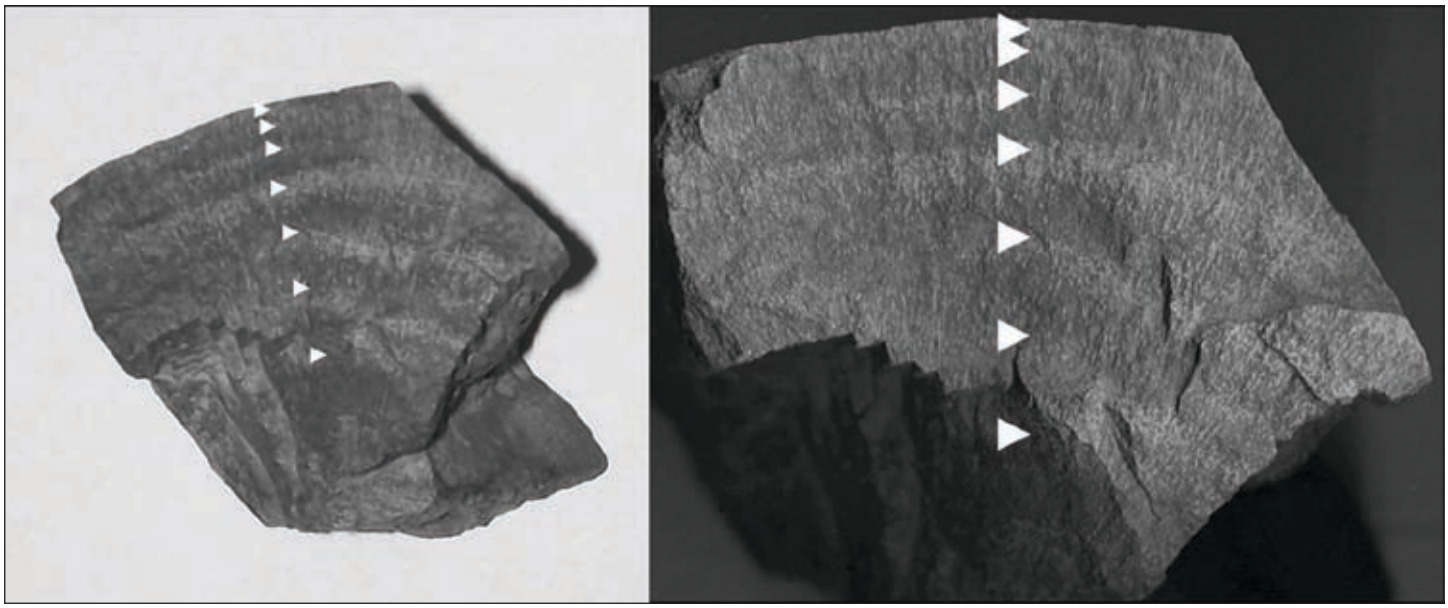
Institutional abbreviation—TSJC, Trinidad State Junior College Louden-Henritze Archeology Museum.

Future research

In the near future, field work at the site should determine whether any additional dinosaur fossils are recoverable. At the moment, a probable theropod ungual found at the site, TSJC 2008.1.3, is tentatively identified as a tyrannosaurid manus claw, though additional work is necessary for a complete identification. As the member in which these fossils were discovered is also poorly known, this member and its relationship to better known strata should be determined. More detailed studies into the abundance of invertebrate macrofossils and other environmental indicators, such



A—A tooth recovered from the locality is clearly tyrannosaurid and bears strong affinities to *T. rex*. Scale bar is 1 cm. **B—**On its anterior carina, the tooth has a serration density of 12/cm, supporting the identification. Serrations are marked with arrows. Scale bar is 1 mm. **C—**Although a limb bone fragment discovered at the locality appears to lack the onion-skin layering that commonly characterizes aged theropod bone, the bone is distinctly layered. These three concentric layers are both three-dimensional and differentiable along the margins of growth lines observed in the bone. The bone also appears to have had a proportionately large medullary cavity, occupying approximately one-third of its 90 mm radius.



White markers along these radial transects indicate the expected position of *T. rex* annual growth markers based on the Erickson et al. (2004) growth equation. The distance between the first (medial-most) and second arrows is 8.5 mm ± 0.5 mm. Tightly packed growth lines near the periosteal margin indicate maturity (Chinsamy-Turan 2005). As expected, based on the close association between these growth lines and the annual growth markers of *T. rex*, this dinosaur would have achieved an asymptotic adult mass identical to *T. rex* (percent difference < 0.003%) based on a logarithmic growth curve constructed specifically for *T. rex* femurs, further bolstering the identification.

as co-occurring *Ophiomorpha* ichnofossils, should also provide insight into the depositional setting.

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