

The Occurrence of *Tyrannosaurus rex* in North Dakota

John W. Hoganson

Introduction

Over the past several years, I've been asking kids to cry out the name of their favorite dinosaur at the beginning of my presentation on the **Rise and Fall of the Dinosaurs**. As a result of this informative, but totally unscientific poll, I have determined that the most popular dinosaur among school age boys is *Tyrannosaurus rex* (often affectionately referred to as *T. rex*). Oddly enough, the girls prefer sauropods, or as they refer to them, the "long necks," even though those dinosaurs were shockingly huge, often many times larger than *T. rex*. I suppose the massive, lumbering, vegetarian sauropods, some up to 120 feet long, were kind of cute. They certainly had small heads and indistinct teeth compared to the giant predators like *T. rex*. Some kids, of course, do not like dinosaurs at all and view them as disgusting beasts. Psychologists have suggested that children are fascinated by dinosaurs because they see them as monsters and yet they know that they are no longer with us, so they are safe from them. Interestingly, even 3rd graders know what the word extinction means primarily because they know that dinosaurs are extinct (the non-avian dinosaurs that is). Most scientists believe that birds evolved from theropod dinosaurs and therefore dinosaurs are still with us today in the guise of birds. I often ask the kids in the grade school tour groups to the North Dakota Heritage Center if they think that *T. rex* lived in North Dakota and, for that matter, the area around Bismarck. About half believe they lived in North Dakota but very few think that they lived in the Bismarck area, just too close to home I guess. We know that *T. rex* lived in North Dakota and near Bismarck because we have found fossils of them in many places around the state, including just a few miles from Bismarck.

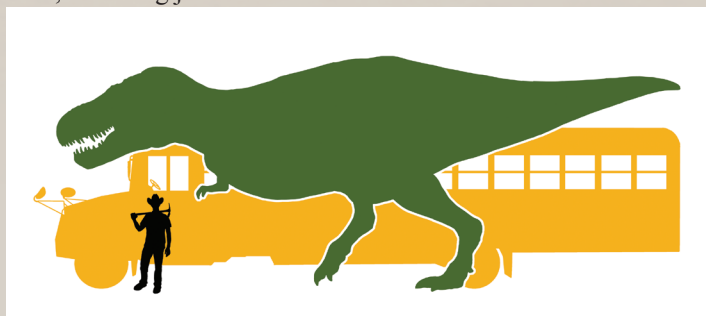


Figure 1. The 42-foot-long *Tyrannosaurus rex* called "Sue" is shown next to a school bus and a 6-foot-tall person for perspective. "Sue" is the largest *T. rex* fossil ever found.

Tyrannosaurus rex

Tyrannosaurus rex was a reptile in the superorder Dinosauria, in the order of dinosaurs referred to as Saurischia, and in the suborder of saurischians referred to as Theropoda. There are many species of flesh-eating dinosaurs within the theropod group. *T. rex* is one of about 700 named species of dinosaurs. *Tyrannosaurus* is derived from the Greek words *tyrannos* meaning "tyrant" and

sauros meaning "lizard." *Rex* is the Latin word for "king." Hence, *Tyrannosaurus rex* is the "tyrant lizard king." *Tyrannosaurus rex* is often incorrectly abbreviated as T. Rex or T-Rex. The correct abbreviation is *T. rex*. In 1905, Henry Fairfield Osborn, a famous paleontologist from the American Museum of Natural History, named this dinosaur based on fossils found in 1902 by Barnum Brown in the Late Cretaceous Hell Creek Formation in eastern Montana (Osborn, 1905). The 1902 specimen, from which *T. rex* was named, resides in the Carnegie Museum of Natural History in Pittsburgh, Pennsylvania. Teeth now determined to be *T. rex* were first discovered by Arthur Lakes near Golden, Colorado in 1874.



Figure 2. Skeleton of the *Tyrannosaurus rex* called "Sue" on display at the Field Museum in Chicago.

Tyrannosaurus rex was among the largest terrestrial carnivores that ever lived on Earth. Two other Cretaceous dinosaur carnivores, *Spinosaurus* and *Giganotosaurus*, were slightly larger. *T. rex* could reach lengths of 12.8 m (42 ft.) from the tip of the nose to the end of the tail and heights of 4 m (13 ft.) at the hips (figs. 1 and 2). The largest discovered *T. rex*, called "Sue," weighed over 7 tons (Erickson et al., 2004); some have even suggested that this animal may have weighed over 10 tons (Hutchinson et al., 2011). Many *T. rex* bones were hollow to reduce weight and compensate for its bulk. Perhaps the most impressive part of *T. rex* anatomy were their heads. Adult heads were 1.5 m (5 ft.) in length from the tip of the nose to the back of the neck. A short, muscular neck supported the head. The huge head and torso were balanced by a long, massive tail. In some ways these animals were oddly shaped with huge, powerful back legs and diminutive, yet also powerful, arms. Each hand had two clawed fingers. A remnant of a third digit on each hand is represented by an additional metacarpal.

Tyrannosaurus rex brandished about 50 teeth at any given time (fig. 3). They were heterodont, that is, their teeth were of different

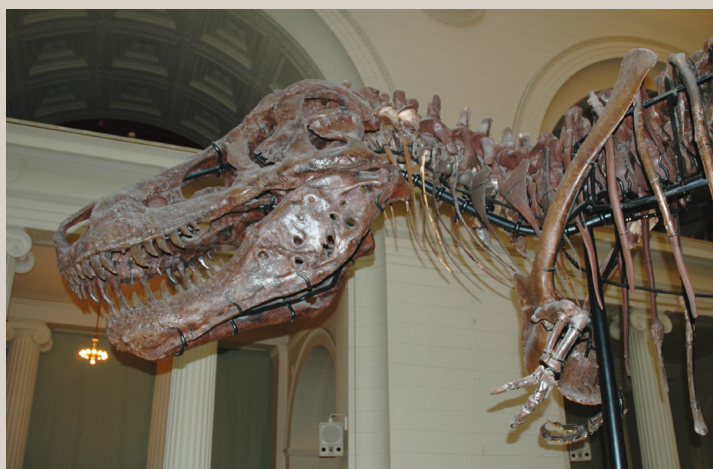


Figure 3. Skull of the *Tyrannosaurus rex* called “Sue” on exhibit at the Field Museum in Chicago.

shapes and sizes in different areas of the mouth (fig. 4). Their teeth were D-shaped in cross section and the tips were laterally compressed and blade-like. Many teeth were robust and banana-shaped. They had the largest teeth of all carnivorous dinosaurs. Some of the largest *T. rex* teeth that have been found reach lengths of 30 cm (12 in.), including the root. *T. rex* teeth were serrated and were used for slashing and ripping into the flesh of prey. The stoutness of the teeth indicates that they could bite into and even break bone; evidence of which is seen on bones of the duckbilled dinosaur *Edmontosaurus* and other dinosaur species that *T. rex* preyed on (fig. 5). It has been estimated that *T. rex* had an incredible potential bite force of 183,000 to 235,000 N (Newtons) (Meers,

2003) compared to dogs that have a bite force of about 3,500 N (Ellis et al., 2008). *T. rex* periodically shed its teeth, similar to a shark. Tooth replacement in theropod dinosaurs may have occurred once every 9 to 16 months, similar to modern alligators, but much less frequently than living sharks which replace teeth on roughly an 8- to 10-day cycle (Farlow et al., 1991).

***Tyrannosaurus rex* paleobiology**

Tyrannosaurus rex is one of the most studied of all dinosaurs. There have been several *T. rex* skeletons, from several age groups, discovered over the past 100 years. Consequently, much is known about *T. rex* and its life habits. The youngest *T. rex* specimen was discovered in eastern Montana and is believed to have been about 2 years old at death (Erickson et al., 2004). It weighed about 30 kg (66 lbs.). “Sue,” both the largest and oldest *T. rex* specimen that has been collected, was found in northwestern South Dakota (figs. 2 and 3). It was over 12 m (40 ft.) long and possibly weighed about 9,500 kg (about 21,000 lbs.) (Hutchinson et al., 2011). “Sue” is believed to have been about 28 years old when it died, probably about as old as *T. rex* would have lived (Erickson et al., 2004). Bone histological studies indicate that *T. rex* grew slowly for the first 14 years of life and then had a growth spurt of about 600 kg (1,300 lbs.) per year until age 18 (Erickson et al., 2004). Growth would then taper off, presumably at maturity. There have been attempts to try to determine the gender of some *T. rex* skeletons, with little success. Like most other extinct prehistoric animals that only leave fossil bones for study, the sex of the animal can rarely be determined.



Figure 4. Examples of *Tyrannosaurus rex* teeth found in North Dakota showing variation in size and shape. The two teeth on the right were collected in Morton County and the one on the left was discovered in Emmons County. Insert is a close up of denticles along one of the serrated edges.

For many years *Tyrannosaurus rex* was thought to have had an erect bipedal posture with its tail dragging on the ground similar to a kangaroo. Because of this, *T. rex* skeletons were displayed in this posture at large museums and early artist renditions of *T. rex* were painted in this way. They were also configured this way in early movies. Through study of *T. rex* bone morphology and by comparison to living animals, it has been determined that *T. rex* could not have sustained an upright posture without damage to its joints and spinal column. Now paleontologists believe that the body of *T. rex* was extended parallel to the ground with its legs positioned under the body, and its tail stretched out to act as a counter balance for its massive head (figs. 2 and 3). Museum exhibits, paintings, and cinema animation now show *T. rex* in this posture.

The speed at which *Tyrannosaurus rex* could run has not been adequately determined and has become a subject of debate. In fact it has even been suggested that *T. rex* may not have been able to run at all. This debate is relevant to whether *T. rex* was an active hunter or merely a scavenger. Estimates of maximum speed for *T. rex* range from a slow 18 km/h (11 mph) and not being able to run at all (no airborne phase in mid-stride like an elephant) to a high of 72 km/h (45 mph). One speed estimation technique for extinct animals is based on preserved tracks and track ways, and measures parameters such as stride. Unfortunately, very few *T. rex* tracks have been discovered, implying to some that *T. rex* may not have been a runner (Hutchinson, 2004). A recent study has shown that *T. rex* could run at about 29 km/h (18 mph) and that speeds of 40 km/h (25 mph) were probably not feasible based on estimates of back leg muscle mass and computer modeling (Sellers and Manning, 2007). To put this in perspective, the fastest human, Usain Bolt, ran the 100 m dash in 9.58 seconds (37.58 km/h; 23.25 mph). So a world-class sprinter could have outrun a *T. rex*.

There has also been a debate whether *Tyrannosaurus rex* was a predator or a scavenger. The debate centers around the unusual anatomy of *T. rex*. Those that propose that *T. rex* was a scavenger argue that its arms were too short to effectively hold prey animals (Horner and Lessem, 1993). *T. rex* arms were ridiculously small for the size of the animal (figs. 2 and 3). Their arms were only about 1 m (3.3 ft.) long but were very muscular as indicated by large muscle attachment points. They would have had great arm strength, and it has been estimated they were capable of lifting more than 200 kilograms (440 lbs.). It is likely they had the strength to hold struggling prey. Proponents for a scavenger lifestyle also



Figure 5. A portion of an *Edmontosaurus* (duck-billed dinosaur) fibula found in the Hell Creek Formation in southwestern North Dakota showing broken bone and gnaw marks caused by a *Tyrannosaurus rex* bite (arrows). Note that the serration pattern of a *T. rex* tooth is preserved on the large gnaw mark.

note that *T. rex* had small eyes - smaller than would be expected if the animal was an active hunter. *T. rex* also had large olfactory lobes indicating that it had a keen sense of smell, a characteristic of scavengers. The *T. rex* active hunter argument is based on its long, massive, and bone crushing teeth, binocular vision, and long, powerful legs (Currie, 1997). Binocular vision is indicated by the placement of the eye sockets, and is found mainly in predators today. Even though *T. rex* was probably slower than most living terrestrial predators, it was still fast enough to catch many prey animals. The majority of paleontologists today view *T. rex* as an opportunistic predator that would also scavenge found carcasses, as do most living predators.

***Tyrannosaurus rex* fossil discoveries**

Remains of *Tyrannosaurus rex* have been discovered in eight states and two Canadian provinces and have been recovered from twelve rock formations (fig. 6) (Holtz, 2007). Although both fairly complete and partial skeletons of *Tyrannosaurus rex* have



Figure 6. States and provinces where *Tyrannosaurus rex* fossils have been found in North America.

been found, most *T. rex* fossils recovered are isolated bones and teeth. These finds indicate that *Tyrannosaurus rex* lived during the Lancian Age of the Late Cretaceous Epoch, from about 68 million to 65.5 million years ago, although there is some indication that this species may have ranged back a bit further in time. They lived in a geographic region referred to as Laramidia, the western part of North America today (fig. 6). At the time a shallow sea, referred to as the Western Interior Seaway, occupied much of the middle portion of North America. This sea divided the continent into two landmasses, Laramidia to the west and Appalachia to the east. Laramidia extended from present day Alaska to Mexico. At the end of the Cretaceous an isthmus, the Dakota Isthmus, connected the two regions in the area now known as North Dakota (Erickson, 1999).

Significance of *Tyrannosaurus rex* in North Dakota

Tyrannosaurus rex remains have been found at several localities in five North Dakota counties: Bowman, Emmons, Morton, Sioux, and Slope (fig. 7). Only one partial skeleton of *T. rex* has been found in the state, in Bowman County. The most common *T. rex* remains collected in North Dakota and elsewhere are shed teeth (fig. 4). Whether one is a school age child, adult volunteer, or seasoned paleontologist finding a *T. rex* tooth is an unforgettable thrill. Fortunately, *T. rex* teeth are at times unique enough to be able to identify them, although often they can not be distinguished from other tyrannosaurid teeth. One obvious characteristic is large size. *T. rex* was the largest predator that lived in North Dakota during the Lancian; no other dinosaur's teeth were as large. But *T. rex* was heterodont so its teeth varied in size (fig. 4). In addition, young *T. rex* obviously would have had smaller teeth than the adults. *T. rex* had serrated teeth. Microscopic analysis of the number and shape of the denticles can be used to aid in identification (Currie et al., 1990). A typical *Tyrannosaurus rex* tooth has up to two denticles per millimeter along the serrated edges (fig. 4). The denticles are stout, chisel shaped, and possess sharp ridges of enamel along the

midline. Distinct blood grooves, directed toward the base of the root occur between the denticles.

Tyrannosaurus rex fossils are found in the Late Cretaceous (68 million to 65.5 million years ago) Hell Creek Formation in North Dakota and one possible *T. rex* tooth has been recovered from the Fox Hills Formation in Emmons County (fig. 7) (Hoganson et al., 2007). During the Late Cretaceous western North Dakota was a huge delta plain and a shallow ocean, the Western Interior Seaway, covered much of eastern North Dakota. The delta was a well-drained corridor that existed between the rising Rocky Mountains to the west and the Western Interior Seaway (Fox Hills Sea) to the east. The shoreline was at about the longitude of Bismarck. As the Rocky Mountains rose through tectonic processes, sediments eroded from them were carried to the east by rivers and streams forming this fan-shaped delta. These sediments, now turned into sandstone, siltstone, and mudstone, are referred to as the Hell Creek Formation; the shallow marine deposits are the Fox Hills Formation.

Many areas of this deltaic plain were forested and contained hundreds of species of plants, mostly small to medium-sized flowering trees (Hoganson, 2006). In some ways, this forest resembled living mixed deciduous and evergreen broad-leaved forests. The plants that grew on the Hell Creek Delta are, however, extinct. One fossil coastal marsh plant community found south of Bismarck contained leaves of cycads, palms, ferns, conifers, and many other exotic plants. North Dakota's climate during the Late Cretaceous was warm-temperate to subtropical probably similar to areas in the southeastern part of the United States today. The woodlands, ponds, and swamps provided abundant habits for many kinds of animals including dinosaurs.

Fossils of about fourteen species of dinosaurs have been recovered from the Hell Creek Formation in North Dakota, including

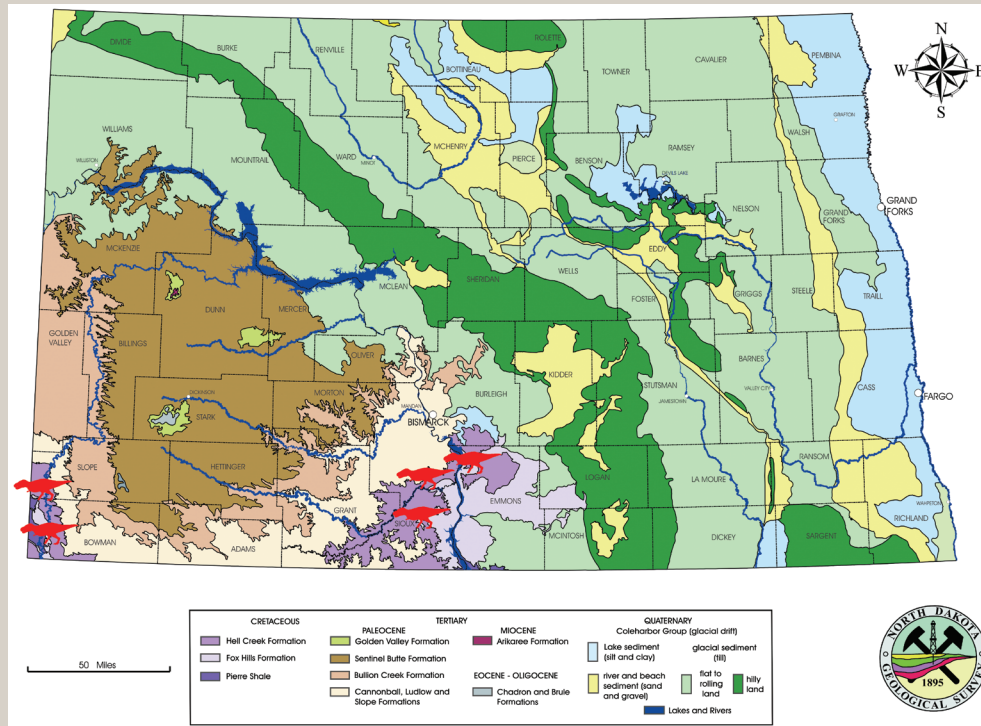


Figure 7. North Dakota counties where *Tyrannosaurus rex* fossils have been found.

Triceratops, *Edmontosaurus*, *Stygimoloch*, *Pachycephalosaurus*, and *Thescelosaurus* (Hoganson, 2006). These herbivores provided prey opportunities for *T. rex* and other predatory dinosaurs. Freshwater fishes, salamanders, lizards, pterosaurs, turtles, crocodiles, champsosaurs (crocodile-like animals), birds, mammals, gastropods, bivalves, and many other creatures co-existed with the dinosaurs (Hoganson, 2006). It is likely that some of these animals also fell prey to *T. rex*.

Discovery of *Tyrannosaurus rex* fossils in North Dakota provides us with greater understanding of the type of environment in which *T. rex* lived, the community of plants and animals that it lived with, its life habits, its geographic range, and time of extinction of the species. Of particular interest is the finding of *T. rex* fossils in Emmons, Morton, and Sioux counties (fig. 7), which indicate that it lived in forested habitats along shoreline areas of the Western Interior Seaway. The occurrence of *T. rex* in Emmons County is extremely important because this find represents the easternmost occurrence of *T. rex* in North America. The finding of *T. rex* fossils in the Hell Creek Formation in North Dakota, where the K/T extinction boundary is well defined, also indicates that *T. rex* was one of the last non-avian dinosaurs to exist before the biological catastrophe that occurred about 65.5 million years ago, when about three-fourths of life on Earth became extinct.

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