

# What Can Be Learned From A Fossil Tooth? An Inquiry Into The Life & Diet Of A Small Theropod Dinosaur

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The Hell Creek and Lance Formations of Montana, North Dakota, South Dakota, and Wyoming (Fig. 1) are valuable sources of Maastrichtian age (Late Cretaceous) fossils. The Maastrichtian is the last age before the well-known Cretaceous-Paleogene (K-Pg) extinction that marked the demise of the non-avian dinosaurs. Studying the fossils of these formations is not only key to understanding the effects the K-Pg extinction had on biodiversity, but understand the biodiversity trends leading up to it. Through understanding these trends as well as the characteristics of

the animals alive at the time, paleontologists strive to understand why the K-Pg extinction seemed to affect dinosaurs so heavily compared to other organisms. Diverse vertebrate remains have been found at these sites, including fish, sharks, amphibians, mammals, reptiles, and birds. The phrase “non-avian dinosaurs” hints that birds are considered dinosaurs, the avian dinosaurs, and this paper will focus on the group that includes birds, their close ancestors, and near cousins: the theropods.

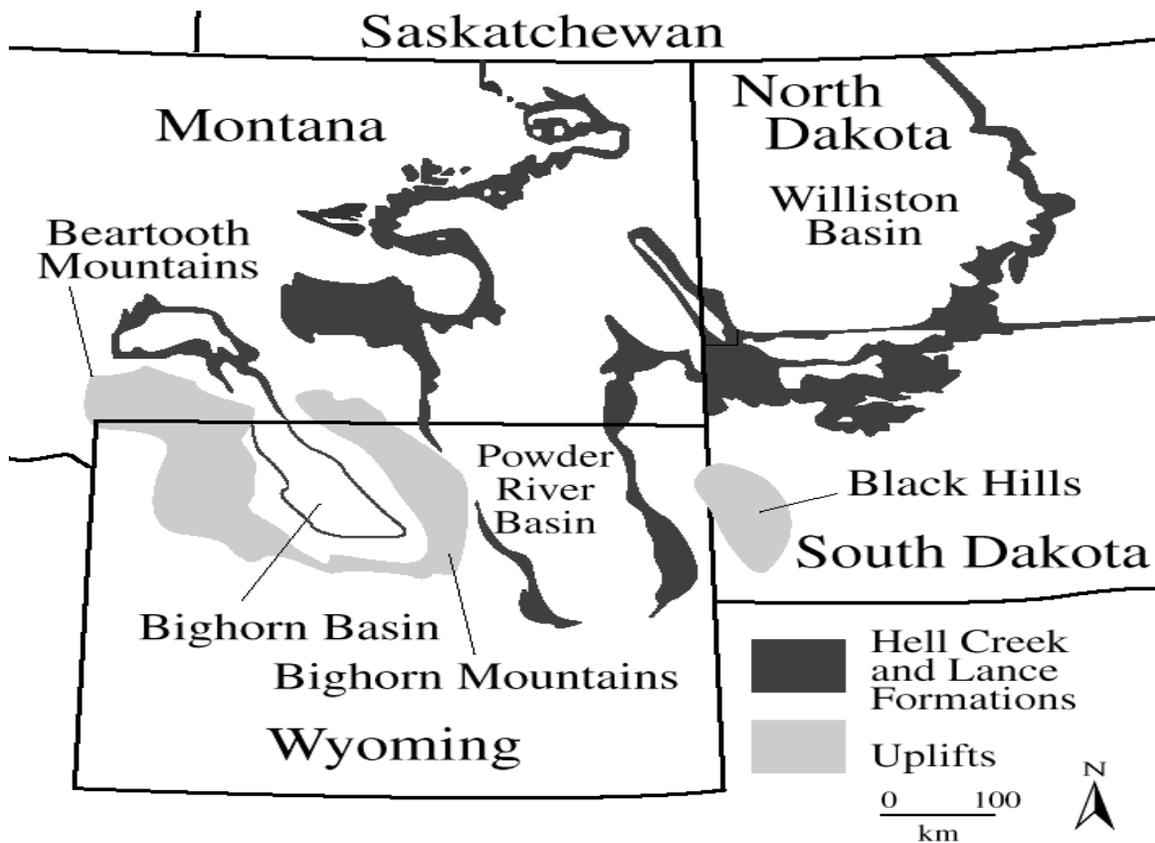


Figure 1: Map of the Hell Creek and Lance Formations. (Modified from Johnson, 1992)



**Figure 2: Recreation of the Late Cretaceous Western Interior Seaway. The Hell Creek and Lance Formations cover areas that were very near water, making fish available as prey animals. (Blakey, 2006)**

If you have ever been to a museum with a dinosaur exhibit, you may have seen a recreation of a large theropod such as *Tyrannosaurus rex* or *Allosaurus*. Indeed, fossil remains of Tyrannosaurids have been found in the Hell Creek and Lance Formations (Longrich, 2008). However, not all theropods are as massive or as well documented as *T. rex*. Two such enigmatic taxa are *Richardoestesia isosceles* and *Paronychodon*, which are known only from teeth. Interestingly, even though only teeth have been found, these two taxa compose over half of all small theropod teeth from Maastrichtian microsites (Sankey, 2008). What were these creatures? Why were they so abundant? To answer these questions, we must first consider what can be learned from a fossil tooth.

### **PREVIOUS STUDIES**

Teeth can offer numerous clues about an animal's diet. We know from our own

mouths that flat teeth for grinding are useful for consuming fibrous plant material, and sharp teeth for puncturing or shearing are good for eating meat. Beyond these very general types, teeth can be grouped for more specific functions. For carnivores, one very important function is the method of seizing and disabling prey. It has been suggested that the straight, isosceles triangle shape of *Richardoestesia isosceles* teeth would be suitable for catching and eating fish (Sankey 2008, Longrich 2008). Because of these observations, we chose to focus on characteristics of piscivorous, or fish-eating, vertebrates.

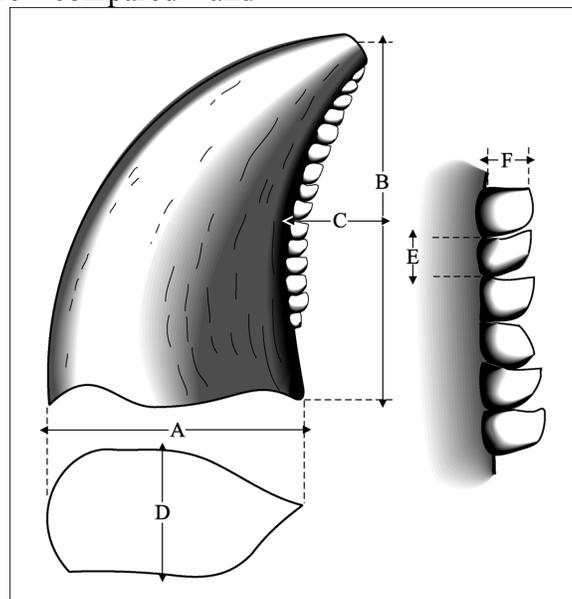
Judy Massare's "Tooth Morphology and Prey Preference of Mesozoic Marine Reptiles" established 'feeding guilds' for ancient marine predators by relating records of stomach contents to the overall shape, robustness, and wear of their teeth. A guild is "a group of species that exploit the same

class of environmental resources in a similar way” (Root, 1967) without considering taxonomy. Therefore, a feeding guild for predators would include animals that consume the similar prey items in similar ways, without necessarily being related. To determine these guilds, Massare used both quantitative and qualitative methods. For the quantitative, two types of ratios were measured from the Mesozoic marine reptile teeth as well as the teeth of modern marine predators such as dolphins and whales for comparison. First was the crown height (the height of the tooth not including the root) to gullet width (the distance between the jaws) ratio to demonstrate the size of the tooth relative to the size of the mouth. Second was the crown height to basal width (the width at the bottom of the crown) ratio for measuring the robustness of the tooth. Qualitatively, wear patterns were examined to further determine robustness, as well as to make inferences about what kind of surfaces those teeth were striking. These ratios and characteristics of taxa with known diets (either from observation of the modern predator’s feeding behavior or fossilized stomach contents) were compared and

contrasted. From this research, Massare was able to make inferences about the diets and ecological niches of the Mesozoic marine reptile taxa for which no stomach content data was available.

## METHODS

**Quantitative:** Using data sets from Sankey, 2008, we calculated basal width to crown height ratios of *Richardoestesia isosceles* teeth and compared them to ratios from Massare, 1987. Because *Richardoestesia isosceles* teeth have ovoid cross sections, we averaged the values of cross-sectional thickness (CST, Fig. 3) and fore-aft to basal length (FABL, Fig. 3) for the basal width values. We calculated ratios from the data set from specimens where the height, CST, and FABL were available and certain. Specimens where some measurements were not listed or the teeth were chipped (making the actual height uncertain) were excluded in the calculations. Because *Richardoestesia isosceles* is only known from teeth, we were unable to calculate the crown height to gullet width ratio.



**Figure 3: Diagram of measurements of a ziphodont tooth. Ziphodont teeth are characterized by the presences of denticles, like the serrations of a knife, as well as recurvature and lateral compression. A = Fore-Aft Basal Length (FABL). B = Crown Height. C = Recurvature. D = Cross-Sectional Thickness (CST). E = Denticle Width. F = Denticle Height. (Sankey, 2008)**

**Qualitative:** We compared the overall tooth shape and wear patterns of *Richardoestesia isosceles* to the tooth morphology feeding guilds presented in Massare 1987.

## RESULTS

**Quantitative:** Values were available and complete for twenty-two specimens from the *Richardoestesia isosceles* data set. The averaged basal width to crown height ratio was 2.9. This ratio falls within the ranges for the General, Pierce II, and Smash feeding guilds described in Massare (1987).

**Qualitative:** *Richardoestesia isosceles* teeth are elongated triangles with slightly rounded yet acute apices. The triangular silhouettes of the teeth (Fig. 4) were most consistent with the Smash guild, and not dissimilar from the General and Pierce II guilds (Fig. 5). However, all of the guilds had teeth with circular cross sections, most of which came from conical teeth. *Richardoestesia isosceles* teeth differ considerable in this respect, as they exhibit the lateral compression of ziphodont dentition characteristic to theropods.

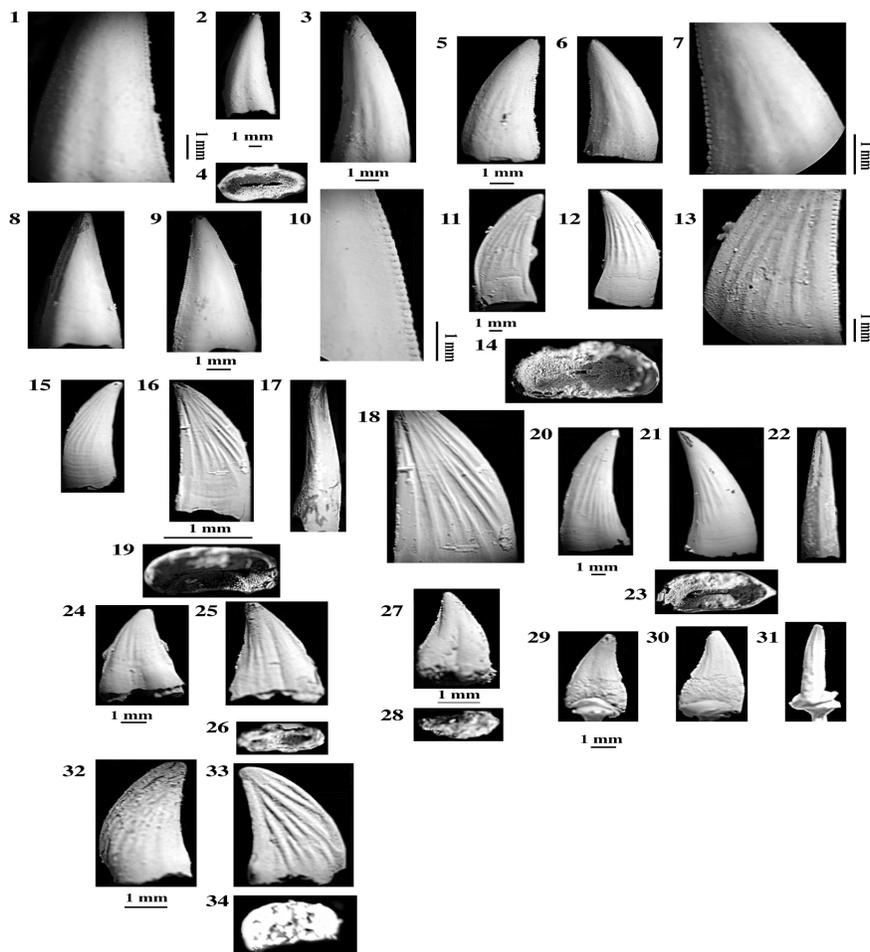
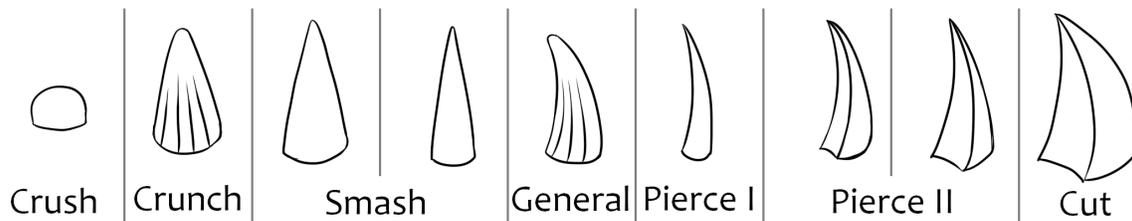


Figure 4: Small theropod teeth from the Lance and Hell Creek Formations. 1-10, *Richardoestesia isosceles*; 11-23, *Paronychodon lacustris* Morphotype A; 32-34, *Paronychodon lacustris* Morphotype B; 24-31 are bird teeth. (Sankey, 2008)



**Figure 5: Tooth morphology-prey type guilds. (Modified from Massare, 1987.)**  
*Richardoestesia isosceles* fit the Smash, General, and Pierce II morphologies and had similar shape ratios.

## DISCUSSION

The basal width to height ratio of *Richardoestesia isosceles* corresponds to tooth morphology feeding guilds called General, Pierce II, and Smash. The General guild and Pierce II guild are similar in that they consist of long yet not delicate teeth suitable for piercing. They are different in that the Pierce II guild has smooth teeth and the General guild has teeth with longitudinal ridges with wear indicative of both piercing and smashing actions. However, Massare notes that this distinction may not be very significant. The Smash guild is characterized by small teeth with rounded tips. Unfortunately, because *Richardoestesia isosceles* is only known from isolated teeth, comparing tooth size relative to the size of the jaw is not possible.

## CONCLUSIONS

Because of the similarity in relative shape, *Richardoestesia isosceles* teeth would be suitable for prey similar to the prey of metriorhynchids, teleosaurs, plesiosaurs, pliosaurs, and ichthyosaurs. This includes small fish and other small aquatic life. Given its tooth shape and environment, it is very possible that *Richardoestesia isosceles* was a fish-eater.

## FURTHER RESEARCH

**Additional Data Collection.** Additional data collection is in progress. Currently, specimens

of piscivorous vertebrates are being examined for comparison at UC Berkeley. In addition to the previous methods, we are looking for qualitative information on the tooth placement and orientation within the jaw, as well as more detailed accounts of tooth wear. Although we do not have any jaw bones for *Richardoestesia isosceles*, we plan to see if there is consistent tooth orientation and wear patterns across fish eating vertebrates. In addition to this, a trip to the University of Washington, Seattle is planned. Many of the teeth identified as *Richardoestesia isosceles* from the UC Berkeley collections are in their possession. While there, more detailed accounts of tooth wear will be recorded. This will be compared with the data collected at UC Berkeley to potentially make further conclusions.

**Stable Isotope Analysis.** Stable isotope analysis is useful for studying aquatic ecosystems. The basic principle is that the higher the trophic level (the higher up in the food chain), the higher the number of heavy isotopes in the animal's body. These heavy isotopes can still be detected even after millennia. The concept is similar to carbon dating. The reason this method is good for aquatic ecosystems is because of the large number of trophic levels within them. In a terrestrial environment, a plant might be eaten by a grazer, and the grazer might be eaten by a predator. But in an aquatic environment,

many predators are themselves prey to larger predators. This dramatically increases the number of trophic levels (links in the food chain) and this in turn increases the levels of heavy isotopes. A chemical comparison of *Richardoestesia isosceles* enamel with enamel of a theropod known to eat terrestrial prey would demonstrate the difference in the number of trophic levels between them, and therefore give clues as to the diet of *Richardoestesia isosceles*.

There are, unfortunately, a few issues with this method. The first is that the sampling method is destructive, and special permission would be needed to destroy the specimens. Secondly, *Richardoestesia isosceles* teeth have thin enamel layers. So it would be difficult to properly sample them, and even then, many teeth would be needed. Although this method would provide some solid information, it is currently impractical. However, if the methodology or equipment

used for analysis is improved, this could be a viable option.

**Biomechanical Analysis.** A biomechanical analysis assesses the forces a body is capable of exerting. In this context, the analysis would focus on the strengths and weaknesses of *Richardoestesia isosceles* for different types of biting motions. Because some believe *Richardoestesia isosceles* and *Paronychodon* may be mutant teeth from many different species, rather than teeth from species of animals, this might help demonstrate whether they are capable of withstanding the forces needed to bite into prey.

#### **Microwear Analysis**

Microwear analysis examines the minute scratches and pits in teeth from their use. This method has been primarily used for mammal teeth, but this may be suitable for our goals. Microwear data from piscivorous vertebrates would need to be collected for comparison.

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