

Senior Capstone:
Ecology of the Late Cretaceous from Hell Creek

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Senior Capstone

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Tyrannosaurus rex is the most researched and well-known dinosaur around the world.¹ Everyone wants to know about the king of beasts, the strongest predator, the bone crushing killer. We know it had eyes the size of oranges, which is the biggest eyes of any predator,² and could discern objects 6 kilometers away;³ it had the strongest bite force of any creature to ever live, and because of its colossal size, it wasn't able to run as an adult.⁴

However, as much as we do know, no one will ever know everything about T-rex or any other extinct species. It is impossible. The world can study T-rex, Triceratops or Edmontosaurus as much as humanly possible with the resources available, and we still wouldn't know close to everything about them. All we have to study the time period of the dinosaurs is fossils, and fossils can only tell us so much. They can tell us what an animal or plant looked like, and the shape of the teeth can tell us if the animal was a herbivore, carnivore, or omnivore. We can even see what kind of habitat the organism lived in based on the plant fossils. If we combine the information from every fossil ever found during the Cretaceous, all we can tell is what lived together in an ecosystem. But unless we have a time machine, we can never tell exactly how that ecosystem operated.

Short of having that time machine, the Hell Creek formation is the world's best look into the late Cretaceous, which was the period ended by the extinction of the dinosaurs.⁵ Located in the states of Montana, Wyoming, South Dakota, and North Dakota, Hell Creek helps us piece together the ecosystem of the final days of the T-rex and the rest of the dinosaurs.⁶ From the fossil record, we know that, surprisingly, Hell Creek had a climate similar to modern-day Northern Florida with at least six somewhat unique habitats—and we know Hell Creek is a floodplain, and that fossils preserve especially well in the slow meandering rivers and swamps that are commonly found in these floodplains.⁷ Regardless of the limitations of our knowledge, the purpose of my research is to share what scientists do know about the six habitats of the Late Cretaceous Ecosystem in North America, including notable flora and fauna.

Context

The first step to understanding the Hell Creek ecosystem of this time period is to understand why scientists even care about it in the first place. As mentioned, The Hell Creek formation is the best place to find and study the ecosystem of Late Cretaceous North America, the period just before the extinction of the dinosaurs. Some of the most famous dinosaurs can be found in the Hell Creek Formation, such as the previously mentioned T-rex as well as Triceratops, Hadrosaurs, Ankylosaurs and a variety of Dromaeosaurs.⁸ One of the unique aspects of the Hell Creek formation is the K-Pg (or K-T) boundary. The K-Pg boundary is a small black line that geologically represents the impact of the meteor that killed the dinosaurs, and this boundary separates the end of the Mesozoic era and the dawn of the Cenozoic.⁹ Therefore, this

¹Parker T., Masna C., Palmer R.(2021). *Saurian:A Field Guide to Hell Creek*. Titan Books. , 117

²Compton, I.(2023, April 20). [Personal Conversation]

³Parker "Saurian:A Field Guide to Hell Creek." 117

⁴Parker "Saurian:A Field Guide to Hell Creek." 117

⁵Compton, I.(2023, April 20)

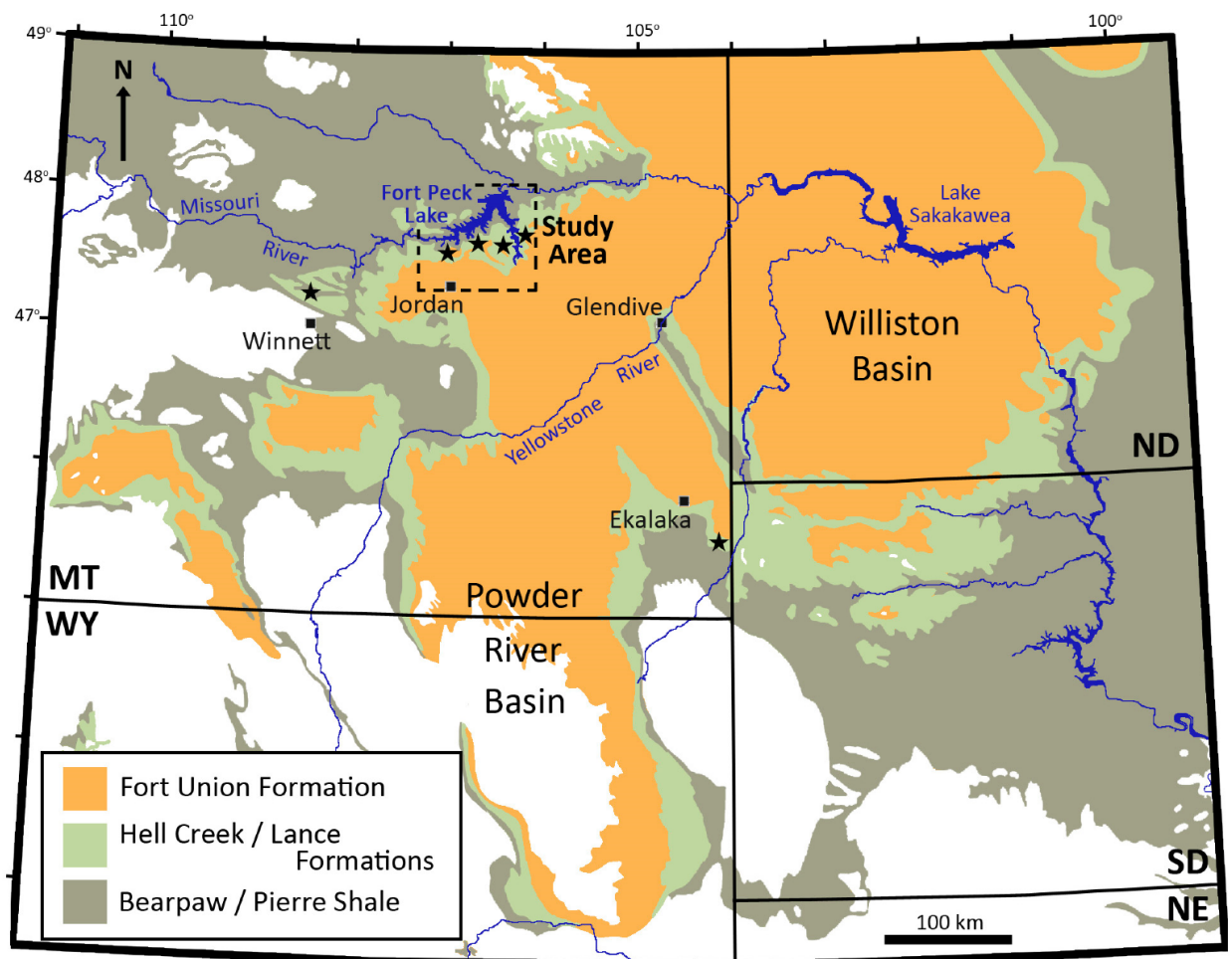
⁶Johnson, Kirk R, et al. Hell Creek Formation: A 2001 Synthesis, 1

⁷Johnson *Hell Creek Formation: A 2001 Synthesis*, 1

⁸Parker "Saurian:A Field Guide to Hell Creek", 8

⁹Johnson *Hell Creek Formation: A 2001 Synthesis*, 2

formation helps paleontologists understand the structure of prehistoric life as well as the extinction event. To immerse ourselves further, we have to understand Hell Creek's climate. The climate of Late Cretaceous North America was a similar environment to modern-day swamps of Northern Florida or East Texas. During the hottest times of year, temperatures would reach up to 82 degrees Fahrenheit, and during the coldest times temperatures would drop to 42 degrees Fahrenheit.¹⁰ Hell Creek was a floodplain that received over three feet of rain per year. It was prone to flooding during the hotter wetter seasons when rain was very common.¹¹ A swampy flood plain with the day-night cycle and bizarre seasonal changes of Hell Creek is non-existent in the modern world. It would have a variation of 8 to 17 hours of daylight throughout the year—hot, rainy season during the portion with extensive daylight, and a cooler dry season during the darkest months of the year.¹² Warm global temperatures combined with the higher concentrations of oxygen in the atmosphere made the late Cretaceous prone to wildfires, so that even plants with a high concentration of water would still burn. This means that fires would be very common, possibly even an annual occurrence. Fires would start most commonly from lightning strikes.¹³



¹⁰Parker "Saurian:A Field Guide to Hell Creek", 12

¹¹Parker "Saurian:A Field Guide to Hell Creek", 13

¹²Parker "Saurian:A Field Guide to Hell Creek", 10

¹³Parker "Saurian:A Field Guide to Hell Creek", 12

Terrain

The Hell Creek floodplain is in between the rising Rocky Mountains and the remnants of the Western Interior Seaway. This basin is usually referred to as the Sheridan Delta. The landscape is covered in woodlands, scrubs, and fields of horsetail surrounding river channels. Cypress was the dominant plant in the floodplain while angiosperm forests populated the drier part of the terrain. Hell Creek itself was nearly a flat plain intertwined with meandering rivers and tangled channels that flowed southeast into the sea. Standing water was predominantly found in horseshoe-shaped ponds called oxbow lakes. Oxbow lakes are formed when erosion causes a river channel to join at a new point. This process cuts off a curved section, and then sediment builds around the edge of the channel, cutting off the curved section and becoming an oxbow lake.¹⁴

Bone Butte

Bone Butte is a Cretaceous waterway that was a secondary stream channel which flowed next to the large central river of the floodplain. Erosion eventually joined this channel with the main river and formed an oxbow lake. The banks of the oxbow would have been overgrown with horsetails, and filled with the aquatic plant *Cobbania*, which is an extinct relative of water cabbage. The forest would be dominated by mostly redwood trees. Swamp cypress would grow in the lake and other frequently flooded areas. Early flowering plants grew farther from the channel, which would make a shrubby forest floor. These shrubs provided shelter and food for small animals, and the large trees would feed the migratory megafauna. This environment made an ideal breeding habitat for local fauna. The oxbow lake would act as a nursery for young turtles, crocodilians and other small aquatic reptiles, and the “Redwood Island” made for a somewhat safe area for the small herbivorous dinosaurs to lay eggs.¹⁵ Bone Butte’s local composition of dinosaurs was different from the general ecosystem of Hell Creek. Instead of the large herds of the migratory huge ceratopsians and hadrosaurs “browsing from fast replenishing groves of flowering plants,” the forest of Bone Butte was home to the smaller herbivores, such as *Pachycephalosaurus* and *Thescelosaurus*, and the fast omnivorous ornithomimids.¹⁶ Birds were common at the oxbow lake, pecking for seeds and insects in the horsetails, and raptors were also present, looking for their next meal. Bone Butte’s redwood forest had a meandering river snaking its way through the center. The water level would lower during the dry season and form oxbow lakes. This area was subject to frequent flooding which kept the land in a constant state of dampness. In the waters, crocodilians lurked beneath dense mats of *Cobbania*, a duckweed-like plant.¹⁷

¹⁴ Parker “*Saurian: A Field Guide to Hell Creek*”, 18

¹⁵ Parker “*Saurian: A Field Guide to Hell Creek*”, 21

¹⁶ Parker “*Saurian: A Field Guide to Hell Creek*”, 21

¹⁷ Parker “*Saurian: A Field Guide to Hell Creek*”, 24

Habitats

Hardwood Forest

Hardwood forests were a common biome all over the greater Hell Creek ecosystem. Hardwood forests made up the majority of the floodplain habitat. Flowering plants had just taken hold by the late Cretaceous, and in the hardwood forest the medium-sized walnut-like tree *Dryophyllum* dominated the canopy, and plane trees were very common around ponds and streams. Erosion from rain and floods carved slopes and banks in the terrain.¹⁸ The understory of the hardwood forest consisted of a diversity of shrubs and small trees, including many laurels. *Triceratops* dominated the area. They would browse on the abundant foliage in small groups. *Tyrannosaurus rex* was also found in this habitat. Fires were common.¹⁹ After a fire, what is known as pioneer species would grow in the cleared ground, ferns would come in first, then small shrubs and herbs, and the habitat would later develop into a flourishing forest again after many years.²⁰

Redwood Forest

The canopy was formed by giant redwoods; their great trunks created a maze for the animals. "In the cool shade below" the canopy of redwoods, "a minor canopy of buckthorn-like shrubs and plane tree saplings" would form in open spots.²¹ These plants would gravitate to wherever sunlight would break through, especially around and along rivers. Groundcover was mainly herbal angiosperms (*Cannabaceae*, *Zingiberopsis*) and chain ferns (*Blechnum*). These fed a large community of *Pachycephalosaurus* and *Thescelosaurus*, and these herbivores would feed the raptors and other small carnivores.²²

Cypress Swamp

Back swamps are common in coastal floodplains. Back swamps are formed by flood waters that get trapped in low areas. We see other puddled habitats on the floodplain "in the form of abandoned tributaries of the meandering rivers."²³ These were common habitats in Hell Creek, and they hosted a variety of flora tolerant to standing water because these areas flooded frequently. Plants such as giant cinnamon ferns, which thrive in bogs, and herbaceous angiosperms (related to modern gingers, hops and cannabis) that grow on curved banks of streams covered what little land wasn't submerged in water. The surface of the water was usually coated in green formed from "Cobbania, a water lily relative (*Paranymphaea*)," and *Azolla*, which is an aquatic fern.²⁴ However, the most prominent were the great cypresses. Extinct species of bald cypress and swamp cypress towered above the swamp. The jagged cypress knees created a maze for small creatures. Cypress knees are stalagmite shaped structures that are made of roots used to anchor the tree in the soft swampy soil. Ancestor of the modern day American Alligator, *Brachychampsa* preyed upon a diverse community of turtles. Birds, mostly aquatic, were also common in this environment. Large dinosaurs such as

¹⁸ Parker "Saurian: A Field Guide to Hell Creek", 28

¹⁹ Parker "Saurian: A Field Guide to Hell Creek", 30

²⁰ Parker "Saurian: A Field Guide to Hell Creek" 29

²¹ Parker "Saurian: A Field Guide to Hell Creek", 35

²² Parker "Saurian: A Field Guide to Hell Creek" 35

²³ Parker "Saurian: A Field Guide to Hell Creek" 38

²⁴ Parker "Saurian: A Field Guide to Hell Creek", 38

Ankylosaurus and Anatosaurus would stay away from the swampy biomes due to the waterlogged soil being very difficult to traverse.²⁵

Fern Prairie

Away from the forest and flood-zones were the open prairie environments of the floodplain. These areas are not frequently in danger of waterlogging and are usually formed from other disturbances, the most common being forest fires or overgrazing from mega herbivorous dinosaurs.²⁶ This habitat is covered with what is known as pioneer species or colonizer species, mostly angiosperms and ferns. Sabalites (an extinct genus of palm) and saplings of plane trees and other common forest species were usually the tallest tree in the biome. The palms would sometimes form small groves which provide refuge for animals in the low scrub. The ground cover was formed primarily by forked ferns. Ferns are not shade tolerant, so they tend to thrive in these areas as well as choke out other herbaceous plants. This made “an abundance of fodder for groups of large herbivores, and flocks of ornithomimids that search for food under the fronds.”²⁷ Grass didn’t exist until 10 million years after the dinosaurs went extinct, so ferns were the plant that covered the ground.²⁸

The Beach

During the Cretaceous, North America was split by the Western Interior Seaway, and Hell Creek is on the western shore of the Seaway. With white sandy beaches along the border, the rivers of the floodplain emptied into the seaway. Salt-tolerant tropical plants lined the edge of the forest with thickets of the cycad *Nilssoniacladus* and the occasional palms. The giant gharial relative *Thoracosaurus* favored salt and sand. It could be found basking on the shores. Toothed birds dove for fish and bigger predators lurked beneath the surface.²⁹

The Bluffs

The bluffline or valley wall defined the outer limits of the floodplain and were “formed from steep slopes and sharp bluffs” that were carved over centuries of shifting meandering rivers, crazy floodwaters and strong winds.³⁰ They housed flora that were more fond of “well-drained soils and less tolerant to flooding.”³¹ Among these plants were several species of “mighty trees” like *Ditaxocladus* (cedar-like trees), Ginkgo, and ancestor of the tulip tree *Liriodendrites*, which was the tallest hardwood in Hell Creek.³² Because it was the driest part of the floodplain, lightning storms tended to set it on fire, so it was often seen in a state of recovery. Species of Ankylosaurs such as *Denversaurus* and *Ankylosaurus* could occasionally be found in the bluffs, most likely when they wandered in from deeper inland. *Pectinodon* were a very common occurrence in the bluffs. They were a small predator that most likely ate mammals and lizards.³³

²⁵ Parker “*Saurian: A Field Guide to Hell Creek*” 38

²⁶ Parker “*Saurian: A Field Guide to Hell Creek*” 42

²⁷ Parker “*Saurian: A Field Guide to Hell Creek*” 42

²⁸ Parker “*Saurian: A Field Guide to Hell Creek*” 42

²⁹ Parker “*Saurian: A Field Guide to Hell Creek*” 46

³⁰ Parker “*Saurian: A Field Guide to Hell Creek*” 51

³¹ Parker “*Saurian: A Field Guide to Hell Creek*” 51

³² Parker “*Saurian: A Field Guide to Hell Creek*” 51

³³ Parker “*Saurian: A Field Guide to Hell Creek*” 51

Flora

The Cretaceous world was populated by dense, and diverse vegetation, and it was the beginning of flowering plants taking over the traditional Mesozoic vegetation, such as ginkgos and cycads. This gave the environment an extremely unique composition that is completely unknown in the modern world.³⁴ All of the plants found and identified are only from their leaves, or a mix of leaves and reproductive structures, which means the reconstructions/drawings of these plants were heavily speculated upon based on their modern-day relatives.³⁵

Ferns

Body fossils, meaning leaf and stem fossils of ferns, are not that common in Hell Creek, but we know they had a very heavy and abundant presence because of their pollen fossils. The most common ones were the large ferns such as cinnamon ferns (Osmundaceae), chain ferns (Blechnaceae) and forked ferns (Gleicheniaceae). There is a noticeable degree of separation among the types of ferns. Osmundaceae grew in swampy environments. Blechnaceae grew in shaded woodlands. Gleicheniaceae grew in dense thickets, environments, and on slopes. Ferns fed the low-browsing herbivores, and Ankylosaurs were particularly fond of ferns.³⁶

Equisetum(Horsetail)

The most common ground plant around lakes, rivers, and swamps were horsetails. These were small plants that grow in dense and expansive thickets around river areas, horsetail plains, and were found almost anywhere sufficiently close to water. They were food for low-browsing herbivores and favored by Thescelosaurus. Thescelosaurus used their long arms and pointed snouts to dig out the horsetail's tubers.³⁷

Ginkgo

Modern ginkgo are called "living fossils" because they are the last remnant of an ancient lineage/species that stretches all the way back to the Triassic. Ginkgo found at Hell Creek are "near-identical" to their modern day trees, and they were only a "minor aspect of the environment".³⁸ Ginkgo are strange in the modern world because their history is unsuited to the habitats that they are distributed in. This could be caused by their evolving in a world dominated by ferns and cycads instead of angiosperms. This may have caused disadvantage to the group, making them displaced by flowering plants in their favored environments. The fruit-like seeds they produce were eaten by herbivorous dinosaurs and then were spread through the dinosaur's excretions.³⁹

Cycadales

In the Jurassic and Early Cretaceous periods before angiosperms, the planet's flora was dominated by ancient relatives of cycads and a group of extinct cycad-like plants called bennettitales. Just like the Ginkgo, these plants were adapted to a world pre-angiosperm, so in the late Cretaceous when angiosperms started to take over and become more common, the Cycads got pushed to the edge of the environment by the flowering plants. A new family of

³⁴ Parker "Saurian:A Field Guide to Hell Creek" 54

³⁵ Parker "Saurian:A Field Guide to Hell Creek" 57

³⁶ Parker "Saurian:A Field Guide to Hell Creek" 58

³⁷ Parker "Saurian:A Field Guide to Hell Creek" 59

³⁸ Parker "Saurian:A Field Guide to Hell Creek" 60

³⁹ Parker "Saurian:A Field Guide to Hell Creek" 60

cycad relatives has been recently discovered called Nilssoniaceae, and very little is known about them. We know that their body fossils show that they grew on thin stems which would most often branch in a “bifurcating pattern,” meaning they would fork in two.⁴⁰ The unique thing about these plants is that they were salt-tolerant and found commonly near the sea. These fossils are rare in the Hell Creek formation, but are very common in the older and coastal Fox Hills Formation.⁴¹

Redwoods

To many, modern redwood forests feel like an ancient place, and for good reason. The dawn redwood (*Metasequoia*) and coastal redwood (*sequoia*) have been around since the Jurassic period, and their modern-day counterparts haven’t changed much, if at all, from the Jurassic. Both of these trees came together to form a huge canopy in the redwood forests of Hell Creek, especially the dawn redwood because of its tolerance to water logging. The third type of redwood was the least common but the most impressive, the giant *Sequoia dakotensis*. The oldest of these trees grew to over 100 meters tall. However, because of their immense size and lack of nutritional value, these trees were rarely fed on from the herbivorous creatures. However, *Anatosaurus* most likely fed on their needles, twigs and occasionally, bark.⁴²

Swamp Cypress

These were medium-sized trees and grew in waterlogged environments, usually by standing water, but they grew along banks of rivers and in frequently flooded terrestrial areas as well. They were a very restricted plant in the Hell Creek ecosystem because of this. However, they were an extremely important part since they are one of the only types of large flora that lives in swamp environments. They are the primary canopy trees in swamps. The fossil record shows there were extensive mats of their needles, twigs, cones and seeds. Because they drop their leaves once a year, we can use them in chronological studies of the layers of rock.⁴³

Cedar

Ditaxocladus shares features of the much more primitive cedars like the Incense and New Zealand Cedars. It is likely what the common ancestor of all cedars looked like. *Ditaxocladus* was unique among the cypress types in Hell Creek; it preferred drier areas of the floodplain. It was also much smaller than the rest of the cypresses, only growing to about 30 meters. This made them much more accessible for herbivores like *Anatosaurus*.⁴⁴

Magnolia

These early angiosperms were “quite the feature of Hell Creek’s canopy.”⁴⁵ They were very large, had horseshoe-shaped leaves and colorful flowers. Being a member of the magnolia family, these trees were very closely related to the modern day tulip tree, and they looked a lot like tulip trees as well. They could be found through a majority of the floodplain forests, but they preferred more open areas where they could get enough sunlight to reach their extreme heights. The leaves of their sapling were also very favored by many herbivorous dinosaurs because they were large and nutritious.⁴⁶

⁴⁰ Parker “*Saurian: A Field Guide to Hell Creek*” 61

⁴¹ Parker “*Saurian: A Field Guide to Hell Creek*” 61

⁴² Parker “*Saurian: A Field Guide to Hell Creek*” 62

⁴³ Parker “*Saurian: A Field Guide to Hell Creek*” 64

⁴⁴ Parker “*Saurian: A Field Guide to Hell Creek*” 66

⁴⁵ Parker “*Saurian: A Field Guide to Hell Creek*” 67

⁴⁶ Parker “*Saurian: A Field Guide to Hell Creek*” 67

Laurels

Laurels were the most diverse and widespread group of flowering plants in the Late Cretaceous. The leaf shapes of Laurels were equally diverse. They ranged from simple tapered point leaves (*Marmathia pearsonii*) to more rounded notched and toothed (*Marmathia trivialis* “*ficus*” *planicostata*) to giant leaves with complex lobed shapes (*Bisonia niemi*). They also varied extremely by genus, but all of them were generally small trees and shrubs. Genetic evidence suggests that the Cretaceous form of Laurels had a different method of spreading their seeds that most modern forms of Laurels don’t possess except for two rare tropical types (*Neocinnamomum* and *Caryodaphnopsis*). Because they were small and common, laurels made up a large part of the diet for the herbivores in Hell Creek.⁴⁷

Monocots

During the early part of the Late Cretaceous, the palms dominated North America, but by the time of Hell Creek they were less common. *Sabalites*, related to modern day palmetto and sharing their fan-like leaves, is a genus tolerant to salty winds of the ocean, and was commonly found around the shores of the Western Interior Seaway. Their large tough leaves made them a very uncommon food for the wildlife, but triceratops are known to have fed off them.⁴⁸

Cobbania hickeyi

This aquatic herb was always seen covering the standing water of Hell Creek. It was a relative to the modern water cabbage, and had a large, flat “water lily-like foliage” that made it float on the standing water of ponds, swamps and lakes.⁴⁹ It is known for many whole-plant fossils, which is very uncommon amongst paleoflora.⁵⁰

Basal Dicots

Dryophyllum was the most common tree in Hell Creek. This tree was small and versatile and can be found almost everywhere in the Hell Creek Formation. It resembles modern day Hickory or Pecan trees, and is a member of the family of the walnut family. *Dryophyllum* was pollinated by wind with long cylindrical flower clusters known as catkins. *Anatosaurus* would eat adult trees, and the saplings were feasted on by shorter herbivores.⁵¹

“*Cinnamomum*” *lineafolia*

Originally classified as a cinnamon bush due to the shapes of the leaves, it now seems to be a member of the primitive family *Trochodendraceae*. This group of prehistoric eudicots have only two members “(*Trochodendron* and *Tetracemntron*).”⁵² These plants were unique as they lacked the “vessel elements in their wood typically thought to be a key feature of flowering plants.”⁵³

Cannabaceae indet., *Humulus* sp.

Members of the *Cannabaceae* were the most common herb in Hell Creek’s ecosystem. This family does include modern day *Cannabis* and hops (*Humulus*). Both types were found near stream beds in dense thickets or as climbing vines, depending on the genus. These were

⁴⁷ Parker “*Saurian: A Field Guide to Hell Creek*” 68

⁴⁸ Parker “*Saurian: A Field Guide to Hell Creek*” 70

⁴⁹ Parker “*Saurian: A Field Guide to Hell Creek*” 70

⁵⁰ Parker “*Saurian: A Field Guide to Hell Creek*” 70

⁵¹ Parker “*Saurian: A Field Guide to Hell Creek*” 72

⁵² Parker “*Saurian: A Field Guide to Hell Creek*” 73

⁵³ Parker “*Saurian: A Field Guide to Hell Creek*” 73

avored by low-feeding or small herbivores like Pachycephalosaurus and ankylosaurs, or juveniles and hatchlings of the larger species.⁵⁴

Rhamnaceae

Rhamnaceae, also known as the buckthorn family, are a primitive group of eudicots. They spread rapidly during the Late Cretaceous. Their foliage, fruits, flowers and pollen are all known from the fossil record, and there were many species present in Hell Creek. *Rhamnus cleburni*, known for their large and serrated leaves, and *R. salicifolius* that are found with leaves are often mistaken for *Dryophyllum*. *Zizyphus fibrillosus* was originally identified as a member of Jujube genus *Zizyphus*, which is where the name comes from. However, later it was reclassified to the pepper family known as Piperaceae, so it was thought to be a climber or herb plant, but later was returned to the buckthorn family, but not as a true *Zizyphus*. These were both understory shrubs, serving as food for herbivores.⁵⁵

Plane Trees

This is a relatively primitive group of flowering plants including the modern plain trees. They were one of the first flowering plants to appear in the mid-Cretaceous. This family (*Platanus*) dominated the late Cretaceous of North America. *Platanites* were one of the most common trees in the late Cretaceous. *Erlingdorfia* was a less common genus in the upper layers of Hell Creek but is easily recognizable by their distinct leaves shaped like *Tyrannosaurus* footprints. These large canopy trees that would grow close to river beds are still the same today as they were millions of years ago. Because they were large, they were out of reach from herbivores, but their saplings were still likely consumed.⁵⁶

Fauna

One of the most incredible and notable aspects of Mesozoic animals were the staggering sizes some of the animals reached. This makes people focus on the size of these animals, but doing this so often “betrays an important nuance” that size estimates are imprecise⁵⁷. Scientists are often forced to come up with the average size of a species from a small number of specimens, all of which vary in size because of many factors such as “diet, age, sexual dimorphism, and other genetic factors.”⁵⁸ The most common vertebrate fossils in Hell Creek are not from dinosaurs, but from aquatic creatures such as turtles, crocodilians and fish. Small land animals like lizards, salamanders and mammals don’t preserve very well in the fossil record and are mostly known from scant remains.⁵⁹

Insects

Insect fossils are extremely rare, and most data about insects comes from damage on leaf fossils made by herbivorous insects. Bone Butte has the best record of insects in Hell Creek because of amber. From these fossils of bugs we see dipteran and nematoceran flies in Hell Creek, and the wing of an ancient greenling (*Hemiphelebiidae*) is also preserved.⁶⁰

⁵⁴ Parker “*Saurian: A Field Guide to Hell Creek*” 73

⁵⁵ Parker “*Saurian: A Field Guide to Hell Creek*” 74

⁵⁶ Parker “*Saurian: A Field Guide to Hell Creek*” 76

⁵⁷ Parker “*Saurian: A Field Guide to Hell Creek*” 80

⁵⁸ Parker “*Saurian: A Field Guide to Hell Creek*” 80

⁵⁹ Parker “*Saurian: A Field Guide to Hell Creek*” 80

⁶⁰ Parker “*Saurian: A Field Guide to Hell Creek*” 83

Fish

The rivers and swamps were occupied by a large variety of fish. A majority of these primitive fish still exist today, like the common garpike *Lepisosteus*. This genus is still alive and thriving today, and their scales are a super common find in Hell Creek. The other very common fish is the guitarfish *Myledaphus*. *Myledaphus* fed on shellfish in the sediment of the river.

Bowfins and relatives of the Bowfin would be found in slow channels and oxbow lakes. For example, *Cyclurus Fragosus* was one of these relatives of the modern day bowfin and reached lengths of 1.5m long. *Melivius*, another ancestor to the bowfin, was a “formidable ambush predator.”⁶¹

Some more bizarre fish like the paddlefish (*Paleopsephurus*) and “the spiny-finned freshwater shark (*Lonchidion*)” which is a survivor from the Triassic period, made rivers a much more dangerous place. The brackish areas of Hell Creek's waters were mostly dominated by sharks and rays. Occasionally we find Carpet sharks (*Restesia*) and nurse sharks (*Protoginglymostoma*) moving up the mouth of the river. The rare and large sawfish *Ischyrhiza* can also be found in this marine environment.⁶²

Amphibians

A variety of salamanders were found in Hell Creek, some tiny and some giant. *Scapherpeton* was among the largest salamanders in the area, and was the most common salamander. The *Scapherpeton* could reach over a meter in length and is a relative to modern-day mudpuppies and olms. Although it was adapted for aquatic habitats, it would not be good at swimming. With its long and robust limbs, it would live in more damp terrestrial places like stream sides and swamps, behaving more like a lizard than a typical salamander. The larger *Habrosaurus*, reaching over 1.5 meters in length, is related to modern day siren salamanders (*Sirenidae*) and had a long eel-like form and truncated limbs. Unlike the *Scapherpeton*, the *Habrosaurus* was mostly an aquatic creature, and could be found most frequently in the swamp habitats of Hell Creek. We can tell from their rows of blunt teeth that they fed on shelled invertebrates and must have had a decently powerful bite. In addition to salamanders, there were a number of frogs that also lived in Hell Creek. These would be relatives of modern day clawed frogs and burrowing toads. They would have rarely been seen by the giant dinosaurs because they burrow underground and were tiny, but their calls would be just as prominent as the trees.⁶³

Mammals

“Contrary to popular belief, mammals had diversified to a great extent by the end of the Cretaceous.”⁶⁴ There were no species larger than a house cat, but they did occupy a variety of niches. There were three major groups of mammals during the Cretaceous period: The *Metatheria* (marsupials and relatives), *Eutheria* (placentals and relatives), and *Multituberculata* (extinct group). Mammals were mostly “represented by small mouse or rat sized tree dwellers.”⁶⁵ Early relatives of placental mammals appeared in Hell Creek; these would explode in diversity

⁶¹ Parker “*Saurian: A Field Guide to Hell Creek*” 84

⁶² Parker “*Saurian: A Field Guide to Hell Creek*” 84

⁶³ Parker “*Saurian: A Field Guide to Hell Creek*” 86

⁶⁴ Parker “*Saurian: A Field Guide to Hell Creek*” 87

⁶⁵ Parker “*Saurian: A Field Guide to Hell Creek*” 87

and evolution after the impact, but in the Cretaceous, placental mammals were the least common out of the three groups. The extinct group of primitive mammal multituberculata was extremely diverse during the Cretaceous, but they slowly became extinct around 35 million years ago. The most common Multituberculate was the groundhog-sized *Meniscoessus robustus*. Metatherians is the group that contains all of today's marsupials, and were very diverse by the end of the Cretaceous. *Didelphodon vorax* (Opossum Tooth) weighed up to 5 kilograms, which was quite large for a Mesozoic mammal. Its bite force was quite impressive for its size, which allowed it to become one of the first active predators/scavengers in the history of mammals.⁶⁶

Turtles

Hell Creek was home to a very diverse collection of turtle species; they occupied many dietary, body size, and environmental niches. Represented by many genera, these animals came from several families. *Cedrobaena brinkman* (Cedar Point Turtle) was a moderate-sized turtle that belongs to an entirely extinct group of stem-turtles called Baenidae. Baenids existed from the Jurassic to the Eocene, and many of their species are known throughout Hell Creek, including the *Gamerabaena* (Gamera Turtle) and *Stygiochelys* (Hell Turtle). The common *Axestemys splendida* (Ax Turtle) was a species of giant turtle that is closely related to the modern day Florida and Yangtze Softshells. Its carapace could reach up to over a meter in length. As the name softshell suggests, it lacked the bony scutes on the shell that most turtles have. They were aquatic carnivores that inhabited many of Hell Creek's freshwater systems. They would feed on fish, amphibians, and invertebrates. The smaller turtles of Hell Creek, *Gilmoremys lancensis* and *Helopanplia distincta*, were also a part of this family, but are more closely related to African and Asian softshells. *Basilemys* (King Turtle) was one of the most unique species of Hell Creek's turtle fauna. It was a member of early turtles that are now entirely extinct (*Nanhsiungchelyidae*). Unlike its turtle brethren which are mostly aquatic, *Basilemys* was a terrestrial animal, living a tortoise-like lifestyle. It roamed the undergrowth of Hell Creek's prairies and forests, feeding on low growing plants, algae and fungi. It favored a drier habitat and was found in the highest points of the floodplain. *Basilemys* was quite large, matching *Axestemys* with a carapace that averaged just over a meter in length. All the other types of turtles were small snapping turtle species.⁶⁷

Lizards

There was a very diverse range of lizards and snakes thriving during the latest Cretaceous, including relatives of iguanas, monitor lizards, gila monsters, skinks and boa constrictors. Most of these were very small, so they likely hid in foliage to avoid detection from the dinosaurian fauna. There were a few exceptions to this, such as the most common lizard in Hell Creek, *Chamops segnisi*. It reached a little more than half a meter in length, which made it a great snack for the smaller carnivorous dinosaurs. *Chamops*, and most other Hell Creek lizards were all part of the extinct group *Polyglyphanodontia*. For a long time, this group was considered to be closely related to whiptail lizards, but recent research indicates that they may have been more closely related to iguanas. *Palaeosaniwa* was a giant, "3 meter long behemoth, that [roamed] the undergrowth of Hell Creek."⁶⁸ Its appearance was similar to a Komodo

⁶⁶ Parker "Saurian: A Field Guide to Hell Creek" 87

⁶⁷ Parker "Saurian: A Field Guide to Hell Creek" 88

⁶⁸ Parker "Saurian: A Field Guide to Hell Creek" 90

Dragon, but it was actually an early relative of the modern day Gila Monsters and Beaded Lizards. Just like its modern day relatives and Komodo Dragons, Palaeosaniwa was venomous, but it was more likely used for defense than killing prey. They had hook-like teeth that would latch onto the target and glands on the lower jaw that would excrete venom into the wound. This animal was a specialized raider of dinosaur nests; it would feed on eggs and young. This made Palaeosaniwa a primary enemy of hatchling dinosaurs.⁶⁹

In the Western Interior Seaway, lived the apex predator of the ocean. Despite its gargantuan size and appearance, Mosasaurus was not a dinosaur. It was not even closely related to dinosaurs. In fact there are no aquatic dinosaurs, only aquatic reptiles. Mosasaurus was a giant marine lizard only found in the Cretaceous period. There is much dispute over where Mosasaurus falls in the lizard family tree, but some recent compelling evidence suggests that they may have been closely related to snakes among living groups. Fossil evidence of the giant mosasaurus in Hell Creek has only recently been discovered, but they have also been found in the underlying Fox Hills Formation. Mosasaurus was truly a monster of the deep. It reached a size larger than T-rex; it was the largest predator of the Maastrichtian world. Mosasaurs would feed on anything they could get their mouths on, including ammonites, fish, sharks, smaller mosasaurs and even dinosaurs if they got the opportunity. Mosasaurs are able to regulate their own body temperature, meaning they were warm blooded, and they gave birth to live young. These are two traits which are a very rare combination in living reptiles. It truly was the most dominant predator of the ocean, having very little competition with the only predator of adult mosasaurs being themselves. They often died of cannibalism, starvation due to their massive size, or predation by the giant predatory fish xiphactinus during their juvenile stages.⁷⁰

Champsosaurs

Champsosaurus was not a crocodile. It was a far more ancient type of reptile that has no living relatives. Champsosaurus inhabited Hell Creek's rivers and swamps, and like most other crocodilians would remain submerged with their heads angled toward the surface with nostrils and sometimes eyes slightly poking out, letting the animal breathe. The animal's skull and specialized structure of the inner ear allowed it to quickly snap its head side to side in order to ambush and capture prey.⁷¹

Eusuchians

Thoracosaurus is a gigantic crocodylomorph that lived in shallow seas of North America and Europe during the Cretaceous and Paleocene. It had a long thin snout and conical teeth; it was specialized for catching fish. It looked very similar to the modern day gharial of India. "It also [resembled] the coeval Champsosaurus in this regard, but [was] unrelated to both."⁷² Thoracosaurus is a Eusuchian which is just outside the group that includes living crocodilians. Thoracosaurus was the rarest of all the Eusuchians in Hell Creek, and it was the largest with some specimens reaching up to over 9 meters in length.⁷³

⁶⁹ Parker "Saurian: A Field Guide to Hell Creek" 90

⁷⁰ Parker "Saurian: A Field Guide to Hell Creek" 90

⁷¹ Parker "Saurian: A Field Guide to Hell Creek" 92

⁷² Parker "Saurian: A Field Guide to Hell Creek" 93

⁷³ Parker "Saurian: A Field Guide to Hell Creek" 93

Short Crocodile (*Brachychampsa montana*)

The somewhat strand *Barchychampsa*, known as the only true crocodilian in Hell Creek, was an ancient relative of modern alligators and caimans. It was smaller than the “stem-crocodilians that share its ecoscape.”⁷⁴ *Brachychampsa* can be identified by its wide, rounded snout and blunt teeth. It used its bizarre teeth to crush the shells of turtles. This gave *Barychampsa* its own niche, avoiding direct competition with the other crocodilian-like animals.⁷⁵

Northern Crocodile (*Borealosuchus sterbergi*)

Borealosuchus was the most common Eusuchian in Hell Creek. Fossils of its teeth and scute are everywhere. This animal had a very similar lifestyle to modern day crocodilians. They would lurk below lakes and rivers, waiting to ambush its prey. It was not a true crocodile, but is the closest known relative to *Thoracosaurus*. Both the *Borealosuchus* and the *Barychampsa* lived long after the extinction of the dinosaurs, and the *Barchychampsa* even lived as late as the Eocene.⁷⁶

Pterosaurs

Pterosaurs are probably the group of extinct animals that is most often mistaken for dinosaurs. They are closely related, but they are not a true part of the group. By the end of the Cretaceous, Pterosaurs had declined in diversity that they showed in the early Mesozoic. The genus *Quetzalcoatlus* is most famous for the giant *Q. northropi*, with its 10 meter wingspan. The species that lived in Hell Creek only reached half of that mighty size but was still a formidable animal. “A stork-like stalker,” these Pterosaurs could be found in open prairies, looking for small animals and baby dinosaurs.⁷⁷ They were excellent flyers, and needed to be as they were easy targets for any carnivore otherwise.⁷⁸

Dinosaurs

Denversaurus schlessmani

One of two types of ankylosaur that is found in Hell Creek, *Denversaurus* was the last surviving member of the family known as *Nodosauridae* (Knobbed Saurians). *Nodosaurids* lacked the iconic tail club that belongs to the ankylosaurids. Regardless of having a club, *Denversaurus* was still heavily armored, covered from head to tail in bony osteoderms, even on the cheeks. This armor included large forward-facing plates on its shoulders that could have been used in territorial shoving matches. Much like all Ankylosaurs, *Denversaurus* was built like a tank. It was relatively safe from predators because of its bulkiness and armor. However, the juveniles, which were much smaller, lacked bone-reinforced osteoderms, which made them an easy snack. Osteoderms are armored structures in the skin of many dinosaurs, named from the Latin terms for skin and bone. They are a piece of bone that is not attached to the skeleton and is embedded in the skin. The bone is usually covered in a hard, scale-like structure called a scute, made from keratin.

⁷⁴ Parker “*Saurian: A Field Guide to Hell Creek*” 94

⁷⁵ Parker “*Saurian: A Field Guide to Hell Creek*” 94

⁷⁶ Parker “*Saurian: A Field Guide to Hell Creek*” 95

⁷⁷ Parker “*Saurian: A Field Guide to Hell Creek*” 96

⁷⁸ Parker “*Saurian: A Field Guide to Hell Creek*” 96

Denversaurus possessed a surprisingly powerful sense of smell, which it would have used to find favored food items and also compensated for its relatively poor eyesight and hearing. Thanks to a recent discovery, we know that this animal had a countershaded color pattern, dark on top and a lighter underbelly, which is a widespread pattern found in nature used as basic camouflage.⁷⁹

Ankylosaurus magniventris

Ankylosaurus was not a common sight, but it would have been an impressive one. Weighing an astonishing six tonnes, the tank-like creature equaled some T-rex specimens in weight despite being only half the length. Ankylosaurus is rare in the upper layers of Hell Creek; it favored an upland habitat away from the coast, which kept it out of the competition of triceratops, which it shared feeding habits with. Ankylosaurus lived off soft, low-growing plants like ferns, leaves, and fallen fruit. They had large muscular tongues that they use to “manipulate food.”⁸⁰ Ankylosaurus best matched the Victorian perception of dinosaurs as big, scaly, slow-moving, and dim-witted. Ankylosaurus is recognized by the giant club on the end of the tail that is used as a predator-deterrent weapon and could shatter bone on impact. The combination of its powerful weapon and near impenetrable armor made the adults nearly invincible to predators or just ignored by predators that were not desperate. Being a territorial animal, Ankylosaurus lived a largely solitary life. Other members of the species were only tolerated during the breeding season. Adult Ankylosaurus did not care for their young, so the young often would have to seek shelter among larger, more intimidating animals while their armor and club developed.⁸¹

Thescelosaurus neglectus

Thescelosaurus was the most unusual and small herbivore in the area. It rarely exceeded 4 meters in length. By modern standards, it was still reasonably sized, but it was easy prey for many of Hell Creek’s carnivores. Thescelosaurus lived in river deltas. Being small, solitary and slow, they stuck to densely vegetated areas where they could hide from predators. Adult Thescelosaurus had a row of bony plates underneath the skin on the sides of their body. It was too large to burrow like its ancient relatives. Thescelosaurus used its strong curved claws to dig up nutritious roots and tubers. They probably were fond of horsetails. “The body of Thescelosaurus is covered in filamentous structures that closely resemble the simple type of feathers.”⁸² Some of these were single, hair-like filaments, while others consisted of multiple filaments extending from a shared point. This anchor point consisted of a flat point. This pattern of skin covering has recently been found in many fossils of another basal neornithischian called Kulindadromeus. These feathers are notable because neornithischians are not closely related to coelurosaurian theropods, which is the group of dinosaurs that include birds and other known feathered dinosaurs. It is unknown if these feather-like structures are related to true feathers. If they are, it may indicate that feathers are a feature of all dinosaurs.⁸³

⁷⁹ Parker “*Saurian: A Field Guide to Hell Creek*” 98,99

⁸⁰ Parker “*Saurian: A Field Guide to Hell Creek*” 100

⁸¹ Parker “*Saurian: A Field Guide to Hell Creek*” 101

⁸² Parker “*Saurian: A Field Guide to Hell Creek*” 102

⁸³ Parker “*Saurian: A Field Guide to Hell Creek*” 102

Anatosaurus (Edmontosaurus) annectens

The giant herbivore, Edmontosaurus or Anatosaurus, had a broad, flat bill, and has been nicknamed the 'duck-billed dinosaur.' Anatosaurus were common in Hell Creek for such large-sized animals, and were generally found more inland than the Triceratops, which dominated the coast. Hadrosaurs would occasionally be found near the coast, but they were usually younger ones that had not yet joined a colony. The duck-like bill would have been used to crop leaves and roots. Then the food would have been grounded down by batteries of hundreds of teeth. Anatosaurus were not as heavily built as Triceratops, but fully grown Anatosaurus were the largest animals in the ecosystem. The very old specimens even rivaled some long-necked dinosaurs of the Jurassic period, reaching a total of 15 meters. These giants were rarely seen with the average size of Anatosaurus being 8-9 meters. Anatosaurus' skull changed drastically in shape as the creature grew. The snout became progressively longer and flatter as it aged. This may indicate that they needed to consume more food as they became increasingly larger. They would have roamed around in huge herds, ranging in numbers of hundreds to over ten thousand. These herds roamed between the uplands and lowlands during the seasons. These great colonies nested together, and raised their young until they were ready to fend for themselves. Then the herd would leave the young to fend for themselves until they were ready to join an adult herd.⁸⁴

Eggs and Nesting

As with birds, the fossil evidence indicates that Mesozoic dinosaurs laid hard-shelled eggs. The amount of young per hatch was mostly large, even in animals that cared for their young. Most species used mounds of substrate--either earth, vegetation or a mixture of the two, similar to modern crocodilians and birds that nest on the ground. Hadrosaurs made dish-shaped nests with a shallow depression surrounded by substrate. Clutches of up to 30 eggs may have been in one nest. These eggs were incubated by the rotting vegetation surrounding the nest.⁸⁵

Pachycephalosaurus

Pachycephalosaurus is famous for their unique domed and thick skulls. They preferred lowland environments. They had an extraordinarily wide rib cage and heavy build, which made them much more massive than other species with similar body length of 4-5 meters. Large specimens are estimated to have weighed near half a tonne. Pachycephalosaurus were a signature herbivore of the forests of Hell Creek because they were able to feed without competition from giant species like Triceratops and Anatosaurus.⁸⁶ Pachycephalosaurus teeth were serrated, and did not have the mechanics for chewing that other herbivorous species possessed. Their teeth were structured for shredding softer vegetation. Pachycephalosaurus skulls had a very large and complex nasal system. Blood vessels in the large nasal opening cooled down blood that went into the brain, which was concealed in walls of bone. These large passages, and a very large olfactory bulb (area of the brain that deals with smell) indicate this animal had a powerful sense of smell.⁸⁷

Their skulls were several inches thick of solid bone, and had spikes and boney nodules. These animals have often been depicted charging at each other at full speed and

⁸⁴ Parker "Saurian: A Field Guide to Hell Creek" 104

⁸⁵ Parker "Saurian: A Field Guide to Hell Creek" 106

⁸⁶ Parker "Saurian: A Field Guide to Hell Creek" 108

⁸⁷ Parker "Saurian: A Field Guide to Hell Creek" 109

clashing heads like rams. Turns out, these animals preferred to swing their heads around like a club, which caused more damage to their target while reducing risk of major injury to themselves. However, we do see accidental headclashing injuries in their skulls. These animals were strongly adapted to withstand this form of combat. Their wide and sturdy rib cage formed a shield for their organs. The dome itself was formed out of a unique type of bone called fibrolamellar bone. Fibrolamellar bone contains a special cell called fibroblast that heals wounded bone.⁸⁸

Their body shape remained relatively similar throughout their life, but the head dramatically transformed throughout their life. The transformation was so great that when remains of juvenile *Pachycephalosaurus* were first found, the dinosaurs were classified as a different species known as *Dracorex*. Jack Horner later disproved the *Dracorex* as a different species by pointing out that reptiles grow differently than mammals. Juveniles completely lack the signature dome--the dome only begins to grow out once they reach the subadult phase of development, and it is only large enough and thick enough for them to use in combat once they reached full adulthood. The dome grew rapidly once the organism reached maturity. The horn-like, bony nodules on the snout cheeks and back of the skull were present from birth.⁸⁹

Triceratops

Triceratops is one the most well-known dinosaurs with its three-horned face being instantly recognizable. Reaching around 9 tonnes at full size, much of this weight was found in the skull. The skull could be over 2 and a half meters in full grown adults. The Triceratops skull fossilizes extremely well. This makes fragments of their skull and horns one of the most common fossils found in Hell Creek.⁹⁰

Triceratops were extremely resilient, and some specimens have survived with their horns, tails, and even snouts partly ripped off. Triceratops preferred more open habitats. They fed on ferns and woody shrubs in contrast with the other multi-ton herbivores (*Anatosaurus* and *Ankylosaurus*) which preferred more forested habitats. They avoided competition with *Hadrosaurs* by keeping to low-growing vegetation while *Anatosaurus* preferred to eat woody leaves from trees. The hooked beak and teeth of Triceratops was well-suited to clipping and shearing the fronds of palms, ferns and cycadales. Body size in adult dinosaurs showed extreme variation. It was often related directly to nutrition or a genetic luck-of-the-draw. This was usually less noticeable in the ornithischian order, and Triceratops is no exception to this. An adult that managed to eat well and avoid stress could grow up to be twice the size of an animal that lived with stress or was born smaller. Because of this, we see some subadult Triceratops that were still growing as large in size as fully grown adults. These immature Triceratops are "the most common age morph encountered in the field."⁹¹ Herbivorous ornithischians, like triceratops, displayed extremely fast growth. They reached sexual maturity in only 3 or 4 years, skeletal maturity between 5 and 8 years, and were full size in around 10 years. As Triceratops aged, it is common for the hard keratin covering on their horns to hollow and weather away, exposing the bone underneath. Going through this full life cycle was rare. "In the brutal world of

⁸⁸ Parker "Saurian: A Field Guide to Hell Creek" 110

⁸⁹ Parker "Saurian: A Field Guide to Hell Creek" 111

⁹⁰ Wilson, G. P. (2014). *Through the end of the cretaceous in the type locality of the Hell Creek Formation in Montana and adjacent areas*. The Geological Society of America. 338

⁹¹ Parker "Saurian: A Field Guide to Hell Creek" 115

Hell Creek,” a large majority of Triceratops did not survive to sexual maturity.⁹² The highest mortality rate was seen in young animals that were vulnerable to small desperate predators like Palaeosaniwa. However, the ones that survived had virtually no real threats other than adult T-rex. This means that those that reached sexual maturity lived on to reach their full size.⁹³

Tyrannosaurus rex

Tyrannosaurus rex is probably the most well-known fossil animal of all, and it has been studied more than any other animal. It was the apex predator of the Hell Creek ecosystem, and is found in every habitat. “Tyrannosaurus [was] an animal of extremes, with many of its attributes being statistical records.”⁹⁴ It was considered the largest land predator that had ever lived, although several other theropods are now in the running for that title. The T-rex was undoubtedly an “enormous animal,” the largest one possibly reaching 9 tonnes.⁹⁵ “Adult Tyrannosaurus [had] the most powerful bite-force measured of any animal in history;” its bite force exerting a crushing 23 tonnes of force or 431,000 pounds per square inch.⁹⁶ Its incredible bite was used not only for killing animals but to break open bones to extract as many nutrients as possible from an animal. Tyrannosaurus rex held a combination of extremely powerful senses. Its olfactory bulbs were larger than any theropod, which gave T-rex an acute sense of smell comparable to modern day vultures. A strong sense of smell is useful for a predator in locating any sort of meal, especially a predator like Tyrannosaurus rex with its huge energy requirements. Like other Coelurosaurs, the Tyrannosaur family’s ear structure was specialized to deal with rapid head movement, and T-rex specifically was adapted to low frequency sounds. Tyrannosaurus’ visual acuity was able to discern objects from 6 kilometers away. This, coupled with a binocular range greater than an eagle’s, meant T-rex was not only able to spot prey from far away, but spot prey accurately.⁹⁷

Tyrannosaurus and its family (Tyrannosauridae) were a peculiar point in the evolution of feathers. Being an early branch of the coelurosaur group, they descended from animals that were covered in primitive feathers. However, Tyrannosauridae reverted back to small scales at some point in their evolution. This might have been from reaching a limit where a covering of feathers would cause the animals to overheat at full size. “If feathers are ancestral to all dinosaurs,” then this is a pattern that has happened many times in animals that reach 3 tonnes or more.⁹⁸

Adult Tyrannosaurus were not capable of running due to their massive size. They had to have one foot kept on the ground, so they could avoid putting too much stress on their joints. This limited adult Tyrannosaurus to a speed of about 27 kph, but they were still fast enough to outrun large prey such as ceratopsians and anosaurs. However, Tyrannosaurus’ body in its younger stages (juvenile and subadult) was very different in comparison to its adult form. They had thin snouts and long, ostrich-like legs. They were much lighter in weight, making them capable of sprinting down agile, mid-sized prey such as Anzu and ornithomimids. Once Tyrannosaurus rex reached 14 years old, they underwent a massive growth spurt, gaining 600

⁹²Parker “*Saurian:A Field Guide to Hell Creek*” 115

⁹³Parker “*Saurian:A Field Guide to Hell Creek*”115

⁹⁴Parker “*Saurian:A Field Guide to Hell Creek*” 117

⁹⁵Parker “*Saurian:A Field Guide to Hell Creek*” 117

⁹⁶Parker “*Saurian:A Field Guide to Hell Creek*” 117

⁹⁷ Parker “*Saurian:A Field Guide to Hell Creek*” 118

⁹⁸ Parker “*Saurian:A Field Guide to Hell Creek*” 118

kilograms a year until they reached 18 years old. When they had almost reached full maturity, their growth then “[slowed] to a crawl.”⁹⁹

Struthiomimus (Ostrich Mimic)

Hell Creek was home to animals of the ornithomimid (bird mimic) family. Different paleontologists have referred to this species as either Ornithomimus or Struthiomimus. Its top speed was estimated to be over 60 kph. Ornithomimids are some of the fastest of all dinosaurs, and its primary form of defense was to run away. Ornithomimids were social animals. They formed large flocks segregated by age. This is a feature they shared with oviraptorosaurs like Anzu. This shows a relationship between herbivory and sociality in theropods.

One of the earliest-known groups of dinosaurs to “have feathers with a central shaft and wing-like structure on the forelimbs” were ornithomimids.¹⁰⁰ The adults were the only ones with these “proto wings,” and they were not used for flight, but for nest brooding and display.¹⁰¹ Ornithomimids were a mostly herbivorous member of the normally carnivorous theropods, the same group that contains T-rex and Acheroraptor. Ornithomimids were browsers. They used their long necks to reach higher-level foliage. Like certain other herbivores, Ornithomimids would swallow small stones (called gastroliths) to help digest tough plant matter. Being opportunistic omnivores, Ornithomimids would take small prey items on occasion like small mammals and lizards.¹⁰²

Anzu wyliei (Bird Demon)

Named after a bird-shaped demon in ancient Sumerian mythology, Anzu was a unique dinosaur in Hell Creek’s collection. Anzu belongs to the oviraptor group, which were once believed to eat eggs because fossil eggs were found with oviraptor, but it was falsely assumed that the eggs were from other dinosaurs because they were actually oviraptor eggs. These animals sat on their eggs like modern-day birds. Anzu were probably herbivores, and they used their wide bill to feed on leaves, fruit and seeds. They had unique musculature that let their lower jaw move forward and backward, allowing them to efficiently shear vegetation. Anzu were commonly found farther inland. This appears to be a niche separation between ornithomimids and Anzu, as ornithomimids were closer to the coast. Anzu preferred the hardwood forest, prairies, and sometimes backswamps. Anzu were social animals, and could be found in small flocks of similarly-aged individuals. Males were much larger than females, and had a more pronounced head crest and feathery displays on the wings and tail, probably used to attract females in breeding season.¹⁰³

Acheroraptor temertyorum (Hell’s Plunderer)

The famous velociraptor from Mongolia and the Acheroraptor are extremely close relatives. They share many similarities to their Asian cousins. Acheroraptor were found throughout Hell Creek, and were primarily nocturnal. Acheroraptor were aggressive for their size, and they often fought and sometimes killed other members of their species. They were also aggressive towards the similarly-sized juvenile Dakotaraptor. Acheroraptor were smart, ruthless and capable hunters. They lived a more solitary lifestyle than the Dakotaraptor. Acheroraptor were opportunistic hunters, so they took a mixture of all types of prey if they got

⁹⁹ Parker “*Saurian: A Field Guide to Hell Creek*” 119

¹⁰⁰ Parker “*Saurian: A Field Guide to Hell Creek*” 121

¹⁰¹ Parker “*Saurian: A Field Guide to Hell Creek*” 121

¹⁰² Parker “*Saurian: A Field Guide to Hell Creek*” 121

¹⁰³ Parker “*Saurian: A Field Guide to Hell Creek*” 122

the chance, sometimes even the decaying flesh of other animals. They utilized the typical raptorial behavior when dealing with animals that noticeably outweighed them, like *Thescelosaurus* or juvenile *Pachycephalosaurus*.¹⁰⁴

Dakotaraptor Steini (Dakota Plunderer)

After recent studies, *Dakotaraptor*'s existence has been brought into question, and might have just been a large *Archeroraptor*. However, its giant size would have forced it to live a much different life than a small *Archeroraptor*.¹⁰⁵ *Dakotaraptor* was one of the largest raptors of the raptor family to have ever lived, beaten only by the *Utahraptor*, which is much older, and did not live in the Cretaceous. However, unlike the *Utahraptor*, the *Dakotaraptor* kept the sleek, long-legged build of the *Acheroraptor*. This allowed *Dakotaraptor* to be a versatile hunter, being large enough to tackle sturdier animals and agile enough to chase smaller prey that rely on speed. "*Dakotaraptor* [was] one of the rarest animals in the Hell Creek ecosystem", only being found on the coast in what is now South Dakota.¹⁰⁶ It occupied a very specific niche of the food web, being an intermediate size between *Tyrannosaurus* and its much smaller relatives. Its teeth and jaws were better adapted for large prey and crushing bones than smaller predators.

Dakotaraptor were also more social than other predators, gathering in a mob around a large carcass. However, these "gatherings" usually ended in combat and cannibalism. Juvenile *Dakotaraptors* lived very differently from adults. They spent their first few years in trees, using their claws and wing-assisted incline running (WAIR) to climb tall trunks and vertical or near-vertical slopes. This gave young *Dakotaraptors* a sanctuary from the dangers on the forest floor. Juveniles were also capable of a limited form of flight called parachuting. This allowed them to safely descend from treetops. Once they reached the sub adult phase, they were too large to effectively do any of these things.¹⁰⁷

Dakotaraptor had a brutal and effective way of hunting. It would jump on top of its prey and use its body weight to pin it down; then it would grab its prey with the raptors' famous foot talon and use its wings to keep itself stabilized. In modern birds, this is known as mantling, but paleontologists call this Raptor Prey Restraint (RPR) in fossil dinosaurs. *Dakotaraptor* could effectively hunt larger animals with a modified version of this technique where it would dig its talons into its prey, inflicting deep wounds, and then eat the prey alive. It had serrated teeth which tore off flesh in strips.¹⁰⁸

Pectinodon bakkeri (Comb Tooth)

Pectinodon were small predatory dinosaurs. They had large forward-facing eyes and accurate hearing abilities. This made them especially effective at hunting at night. They had long legs that allowed them to chase down prey and would kill using the large claws on their feet. *Pectinodon* were omnivorous and would eat plants and eggs.

Pectinodon were very closely related to birds, and share many similarities. *Pectinodon* is among the family that is thought to be the most intelligent of the non-avian dinosaurs (Troodontidae). Its brain to body size ratio matched that of living birds. Dinosaurs that are close to the origin of birds such as *Pectinodon*, *Anzu*, and *Acheroraptor*, all have the same type of

¹⁰⁴ Parker "*Saurian: A Field Guide to Hell Creek*" 124

¹⁰⁵ Compton I. (2023, April 20)

¹⁰⁶ Parker "*Saurian: A Field Guide to Hell Creek*" 127

¹⁰⁷ Parker "*Saurian: A Field Guide to Hell Creek*" 128

¹⁰⁸ Parker "*Saurian: A Field Guide to Hell Creek*" 129

feathers as modern day birds. The feathers have a central quill that branches into barbs and some smaller barbules. Like the flight feathers of modern birds, some of these feathers are asymmetrical. These feathers form the fans on the tails and wings. This includes the flightless species mentioned, as well as smaller, non-flightless species, which begs the question: If these feathers were not used for flight what were they used for? Theories say that some species may have used it for sexual display. Some species covered their nest while brooding (like *Pectinodon*) while others may have used them to assist in balance during hunting like *Dakotaraptor*, or perhaps a combination of uses existed depending on the animal.¹⁰⁹

Avifauna

Hell Creek was also home to a variety of birds. Some of these species belonged to groups that disappeared at the end of the Cretaceous, such as the toothed birds, but others belonged to the modern bird group that has survived until today¹¹⁰

Toothed Birds

Opposite birds (enantiornithes) were the most primitive type of birds in the ecosystem. They had a full set of teeth and clawed wings. *Avisaurus* (meaning Bird Saurian) was one of the last of the group and was the largest bird in Hell Creek. The *Ichthyornithean* was a coastal animal that lived along the shores of the Western Interior Seaway. It filled the same niche as modern day seagulls. They had some teeth and a bill “at the tip of the upper jaw, which [aided] in catching slippery fish.”¹¹¹ *Hesperornithes* was another extinct group of birds that inhabits Hell Creek. Members of this group included *Hesperornis*, which were “large, flightless seagoing creatures.”¹¹² However, *Brodavis* was a small primitive member of this group, and it retained wings and was still able to fly. Despite being able to fly, it most likely spent most of its life floating on the water diving for fish. *Potamornis* (River Bird) was an advanced member of the *Hesperornithes*, and was similar to *Hesperornis* in form. *Potamornis* was a good swimmer, but it was completely flightless.¹¹³

Modern Birds

At some point in the Late Cretaceous, the group that encompasses all modern birds appeared and began to diversify and spread. *Styginetta* resembled a flamingo, but it is actually related to the waterfowl. These birds used their specialized beaks to filter feed for tiny plants and animals in the swamp habitats. It was one of the more common birds in Hell Creek, and they were found around the wetland of Hell Creek. They were also one of the largest species, only rivaled by the toothed *Avisaurus*. *Styginetta* remarkably survived the great extinction. Most of the modern birds that inhabit Hell Creek occupied a water-dominant habitat very similar to modern day wader-type birds. Their wide, thin toes allowed them to walk on the soft mud, and their narrow bill was used to probe for small invertebrates and seeds. One of the most widespread modern bird groups at the end of the Cretaceous was the *Cimolopterygidae*

¹⁰⁹ Parker “*Saurian: A Field Guide to Hell Creek*” 130

¹¹⁰ Parker “*Saurian: A Field Guide to Hell Creek*” 132

¹¹¹ Parker “*Saurian: A Field Guide to Hell Creek*” 133

¹¹² Parker “*Saurian: A Field Guide to Hell Creek*” 133

¹¹³ Parker “*Saurian: A Field Guide to Hell Creek*” 133

(Cretaceous Wings). This family included Cimolopteryx and Lamarqueavis, and this group greatly resembled modern shore birds. These birds were present in Hell Creek but were more common farther south in the Lance Formation (which is after the Cretaceous).¹¹⁴

Small Dinosaurs, Modern Days

Every bird that is alive today is a part of the group that includes all of these dinosaurs. There has been lots of discussion as to why this specific group of dinosaurs (birds) survived the mass extinction of the great Cretaceous while all other groups died out. Their survival has been most likely caused by their close ties to water, which was a better safe haven than terrestrial habitats. Another factor that may have given them an advantage was their incredibly fast growth rates compared to other primitive birds. Recently, their survival has been attributed to their “omnivorous diet; specifically their ability to feed on seeds [which] may have offered a more sustainable food source.”¹¹⁵ However, in reality, their survival is most likely a combination of all these factors and a little bit of luck.¹¹⁶

Conclusion

Despite the limitations that come with paleontology, it is astonishing how much we can find out from what little information is available from the fossil record. Much of these amazing discoveries can be attributed to luck. Specimens like Dakota have allowed us to dive deeper into the life of Edmontosaurus.¹¹⁷ The fossil record not only allows us to piece together a dinosaur skeleton—it has helped us construct this picture of an ecosystem.¹¹⁸ Paleontology may not be able to discover everything about life from the Cretaceous, and no matter how much we study we won’t know everything, but despite that, we push through to discover as much as possible about the history of this planet. Fossils are the gateway to the past, and will continue to be, until we build a time machine.

¹¹⁴ Parker “*Saurian: A Field Guide to Hell Creek*” 134

¹¹⁵ Parker “*Saurian: A Field Guide to Hell Creek*” 135

¹¹⁶ Parker “*Saurian: A Field Guide to Hell Creek*” 135

¹¹⁷ Manning, P. L. (2010). *Dinomummy: The life, death, and discovery of Dakota, a dinosaur from Hell Creek*. Kingfisher.

¹¹⁸ Johnson *Hell Creek Formation: A 2001 Synthesis*, 3

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