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Author(s): Jack Wilkin
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Patterns in Palaeontology: The Real Jurassic Park

by Jack Wilkin [*1]

Introduction:

The Morrison Formation is renowned worldwide as one of the world's most significant locations for dinosaur fossils. It covers more than 150 million square kilometres, running from Alberta in Canada to New Mexico in the United States, and from Idaho across to Nebraska (Fig. 1). The Morrison dates to the Oxfordian stage of the late Jurassic period, some 155 million to 148 million years ago. It is what is known as a Konzentrat-Lagerstätten, meaning that it has a very high concentration of fossil remains, with extensive bone beds created by flash floods depositing lots of bones in one place. The Morrison provides palaeontologists with remarkable insight into a late Jurassic terrestrial ecosystem. Not only does the formation contain some of the largest dinosaurs ever found, but it also hosts the most diverse group of mammal remains yet known from the Mesozoic era (252 million to 66 million years ago).

Geological setting:

The Morrison Formation comprises mainly mudstones, sandstones, siltstones and limestones. The rocks are light grey, greenish grey and red owing to fossilized soils, called palaeosols (Fig. 2). The formation once included a range of environments, from swamps complete with coal deposits in the north to desert conditions in the south. Overall, the environment was dry and savannah-like, prone to flash floods.

In the states of Colorado, Utah and Wyoming, the rocks in the Morrison Formation are mostly made from river and lake deposits. Many of the fossils are partly disarticulated, or broken up, because the animal's body was carried along by a river before being buried in a sand bar. The formation contains some species that would have lived in fresh water, such as amphibians, which suggests that the area contained permanent freshwater lakes.

The Morrison was dated to the Oxfordian stage using radiometric dating — which measures the abundance of radioactive chemical elements and their decay products — and biostratigraphy, in which layers of rock are dated by comparing the fossils found in them. The Morrison Formation is also a major source of uranium ore; in fact, the radiometric dating used uranium and lead (U–Pb).

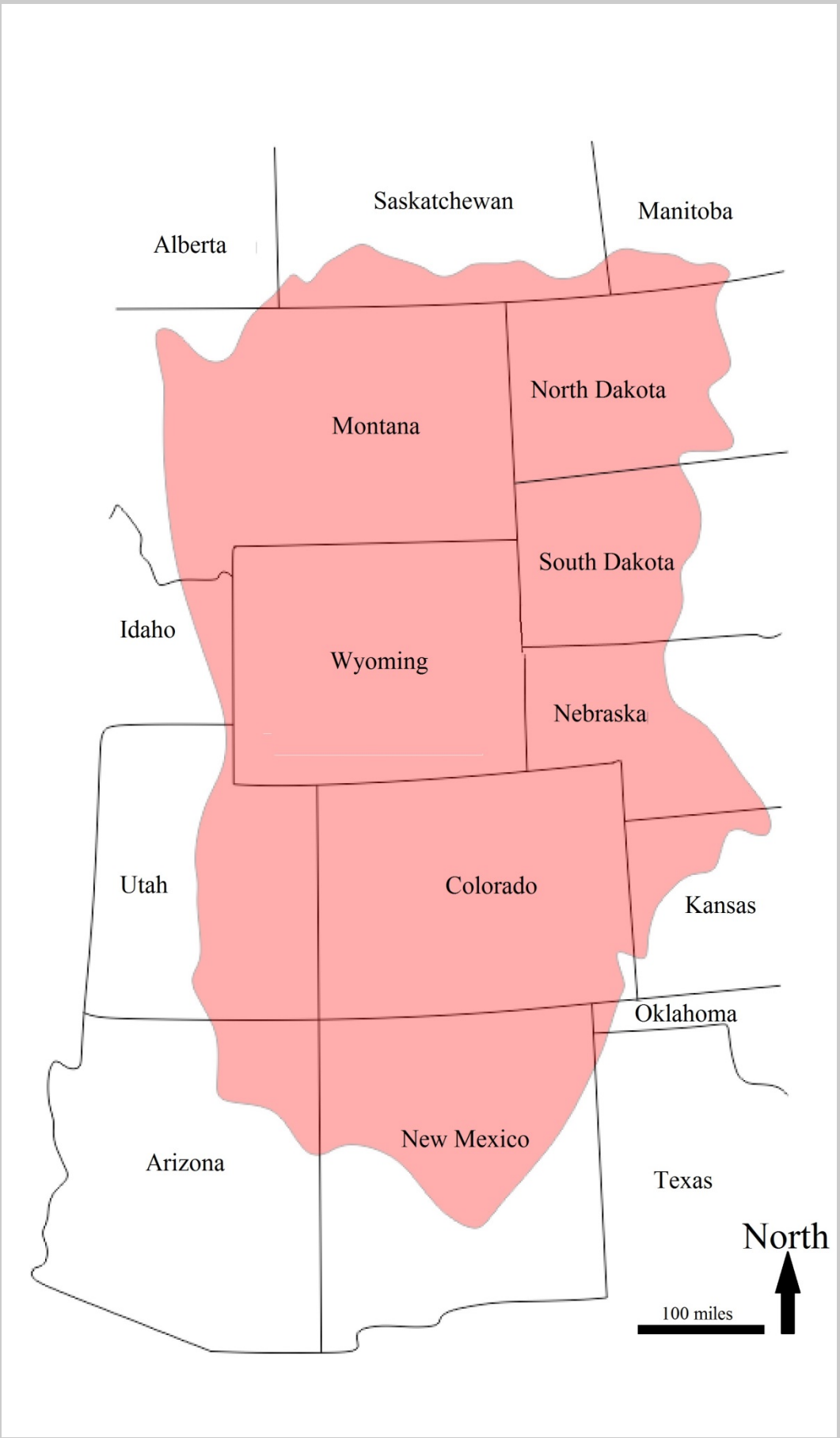

Figure 1 — Map of the Morrison Formation. Author's own work.

Figure 2 — The distinctive banding of the Morrison Formation originated from muds and sands laid down by ancient rivers. Photo by Michael Overton. Licensed under CC BY-SA 2.5 via Wikimedia Commons.

Dinosaur National Monument:

The Morrison Formation is best known for its dinosaur bone beds, such as Dinosaur National Monument and the Cleveland–Lloyd Dinosaur Quarry. A bone bed is a sedimentary deposit that contains remains of multiple individuals in unusually high concentrations.

Established in 1915, the Dinosaur National Monument is an 850-square-kilometre national park on the border of Colorado and Utah. It contains stream, lake and swamp deposits. The dinosaurs and other ancient animals were washed into the area and buried, presumably during flooding. The park includes a quarry with a tilted rock layer that contains hundreds of dinosaur fossils. This is now enclosed by the Dinosaur Quarry Building to protect it.

The Cleveland–Lloyd Dinosaur Quarry:

The Cleveland–Lloyd Dinosaur Quarry in Utah contains some of the best evidence of theropod dinosaurs — the group that includes *Tyrannosaurus rex* — anywhere in the world. It is also the largest collection of theropods in the world, having yielded more than 50 *Allosaurus* skeletons, representing a number of stages of growth. *Allosaurus* is the most common species at the site; other theropods are known, but in much lower numbers. Herbivorous dinosaurs are also present, but are very rare. The ratio of predators to prey is 3:1, so the site was probably a 'predator trap'. The rock entombing the specimens was once mud, and it is theorized that herbivorous dinosaurs became trapped in the mud around a small pond. As the herbivore struggled, its calls alerted predators and scavengers that themselves became trapped. Overall, at least 70 different dinosaur specimens are known from the quarry.

Plants:

Vegetation from the Morrison is similar to that in other Jurassic sites, such as the Lourinhã Formation of Portugal and the Tendaguru of Tanzania. It is dominated by ferns, conifers, cycads — plant that look similar to palm trees but aren't closely related to them — and ginkgos. Insects became more diverse in the Jurassic, with some groups becoming involved in plant reproduction by transferring pollen from one plant to another. It is generally accepted that flowering plants (Angiosperms) evolved in the early Cretaceous period, between 146 million and 100 million years ago.

Pterosaurs:

In the skies above the dinosaurs were flying reptiles called pterosaurs. Like the dinosaurs, they evolved in the Triassic period (starting 252 million years ago) and died out at the end of the Cretaceous, 66 million years ago. Although some species became very large, they were able to fly because they had hollow bones. Their wings were made of a thin skin membrane supported by an extra-long fourth finger. Pterosaurs are preserved only rarely in the Morrison Formation, mainly because their bones were very fragile. Pterosaur finds from the Morrison include both the long-tailed rhamphorhynchoids and the more advanced short-tailed pterodactyloids. Morrison pterosaurs fed on fish and scavenged dinosaur carcasses.

Mammals:

The Morrison is the most important Jurassic mammal assemblage in the world, providing invaluable insights into early mammalian evolution. Mammals at this time occupied a wide range of ecological niches. For example, *Fruiafossor* was a termite-eater that closely resembled living anteaters. This is a remarkable example of convergent evolution, because numerous skeletal features suggest that the two groups are unrelated, so they developed a similar body plan in response to a similar lifestyle.

The mammalian groups found in the Morrison include: symmetrodonts, the carnivorous eutriconodonts, dryolestoids and the rodent-like multituberculates. Of these groups, only the multituberculates survived the extinction at the end of the Cretaceous that also killed most of the dinosaurs. They did go extinct during the Eocene epoch, between 56 million and 34 million years ago, but they still have the longest fossil history of any mammal group, lasting for more than 140 million years.

Mesozoic mammals were small and mainly nocturnal. A study in 2009 concluded that the genus *Docodon* was the largest at 141 grams, and *Fruitafossor* was the smallest at just 6 grams.

Ornithopods:

Ornithopods were herbivorous dinosaurs that walked on two legs and came in several types. Small hypsilophodonts included *Drinker*, *Nanosaurus* and *Othnielia.* Larger but similar-looking dryosaurids were represented by *Dryosaurus*, and the camptosaurids by *Camptosaurus*. Both dryosaurids and camptosaurids were early iguanodonts, a group that would later spawn the duck-billed dinosaurs.

Figure 3 — *Allosaurus* vertebra with a puncture that perfectly matches a stegosaur tail spike. Image courtesy of Kenneth Carpenter.

Duck-billed dinosaurs (or hadrosaurs) were the most successful group of dinosaurs in the Cretaceous. As well as bones, ornithopod egg shells have been found in the Morrison.

Thyreophorans:

Thyreophorans are often called armoured dinosaurs because of their armour plating. The most famous of these from the Morrison is *Stegosaurus*. It had a row of plates running down its back that might have

been used to regulate its temperature. Its tail sported a set of four spikes, which would have been used for defence (Fig. 3). At least three species are known from the Morrison Formation, from the remains of about 80 individuals.

No armoured dinosaurs apart from stegosaurs were known in the formation until the 1990s. Since then, two have been named: *Gargoyleosaurus* and *Mymoorapelta*. Both are ankylosaurs, with *Gargoyleosaurus* being one of the earliest of this group represented by complete fossils. Ankylosaurs are best described as dinosaurian tanks, with their heavy armour projecting them from predators. Later ankylosaurs from the Cretaceous even had tail-clubs and armoured eyelids.

Heterodontosaurs:

Heterodontosaurs first evolved in the late Triassic period and continued until the early Cretaceous. The name comes from the Greek for 'different tooth', and indicates that each animal had several kinds of teeth. Many species had a large third tooth that resembles the canines of carnivorous mammals.

The only heterodontosaur known from the Morrison is *Fruitadens*. It was the smallest dinosaur from the formation, at 75 centimetres long. It, and other heterodontosaurids, might have been omnivorous. A study in 2012 suggested that *Fruitadens* was an ecological generalist, eating both plants and insects or other invertebrates.

Sauropods:

Sauropods were the largest land animals that ever existed. Complete fossil finds are rare: many species, especially the largest, are known only from isolated and disarticulated bones. Sauropods were herbivorous, generally with long tails, long necks and tiny heads. They had pillar-like legs and massive bodies. Such huge animals would have had an enormous impact on the environment, being capable of clearing sections of forests. Sauropods, like most dinosaur groups, could not chew, so had to swallow food whole. To help grind food down and make digestion more efficient, they swallowed stones called gastroliths.

Diplodocus was a gigantic dinosaur at 27 metres in length. The neck had 15 vertebrae and was held horizontal to the ground (Fig. 4). *Diplodocus* could use its tail as a whip. Some palaeontologists have suggested that the tails were used as defensive weapons. More recently, several have speculated that, like bullwhips, such tails were noisemakers used for communication.

Apatosaurus was like diplodocids but had a bulkier skeleton. *Diplodocus* weighed about 12 tonnes, but *Apatosaurus* would have been 20 tonnes even though it was 7 metres shorter.

The middle stages of the Morrison Formation were dominated by the giraffe-like *Brachiosaurus*, which was able to hold its head vertically so it could browse the tops of trees up to 16 metres tall. This titan reached a length of 20 metres and a weight of 50–80 tonnes, and required 240 kilograms of food per day. *Brachiosaurus* is almost identical to *Giraffatitan* from East Africa, so much so that some palaeontologists consider them to be the same genus.

Figure 4 — *Diplodocus* and *Allosaurus* from the Muséum national d'Histoire naturelle, Paris. Authors own work.

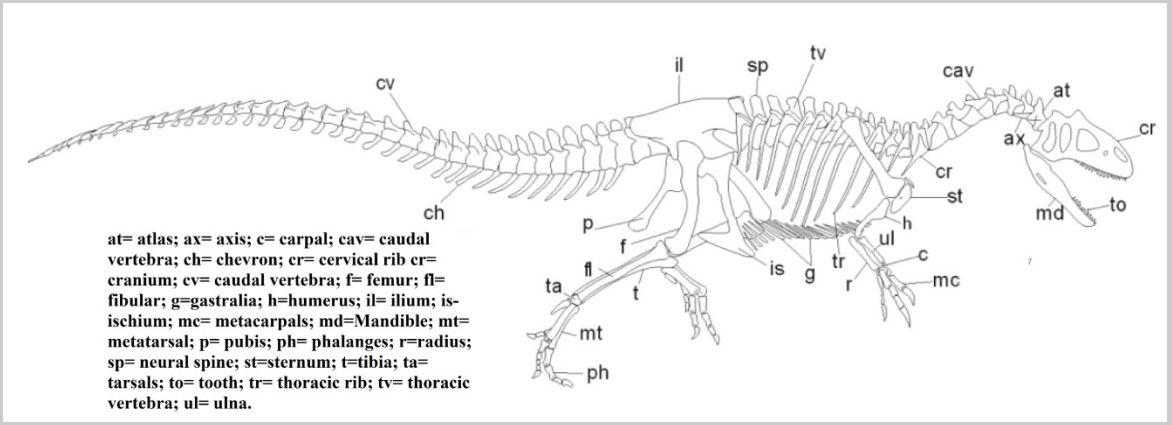

Figure 5 — Skeletal reconstruction of *Allosaurus*. Author's own work.

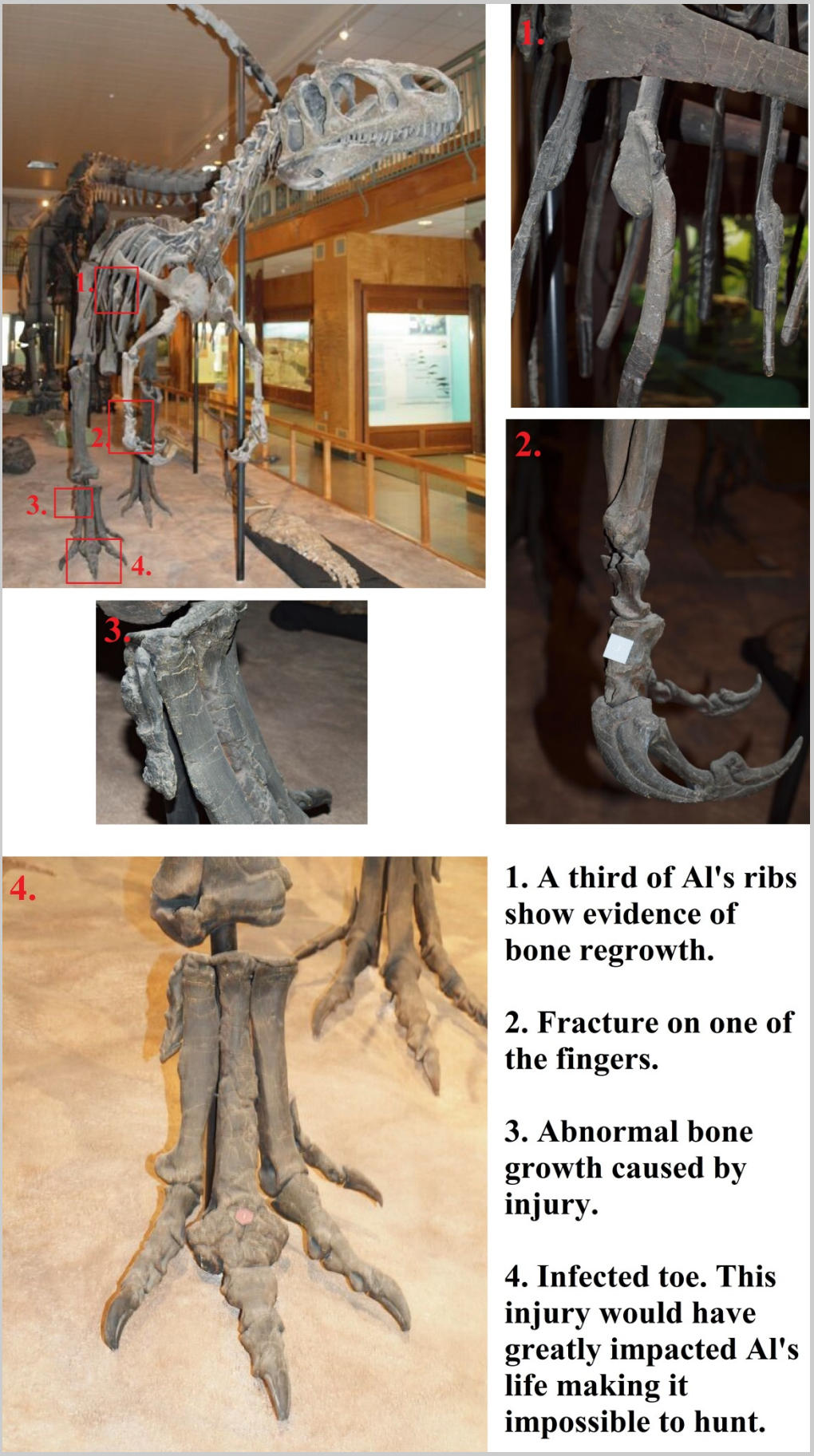

Figure 6 — Big Al the *Allosaurus* and his pathologies. Image courtesy of Laura Vietti.

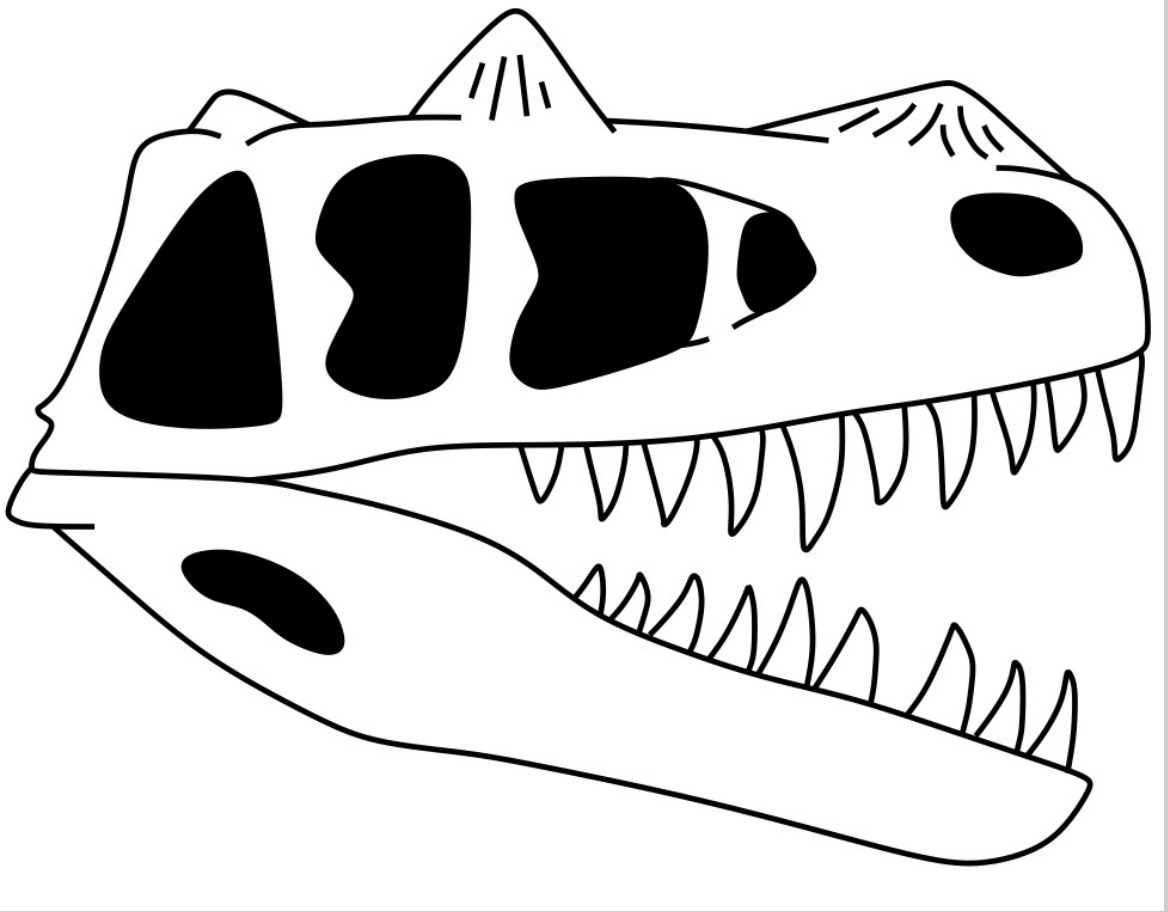

Figure 7 — Diagram of *Ceratosaurus* skull. Author's own work.

Theropods:

The group Theropoda was mainly carnivorous, although several members evolved herbivorous, omnivorous or insectivorous diets. Theropods were the sole large terrestrial carnivores from the early Jurassic until at least the close of the Cretaceous. They are the only group of dinosaurs that have descendants alive today: birds evolved from small, specialized coelurosaurian theropods in the Jurassic. Today, there are between 9,000 and 10,000 living species.

Allosaurus was a massive carnivorous theropod that lived in what is now North America, East Africa and Portugal, making it one of the only dinosaurs known from multiple continents. Most specimens, however, come from the Morrison Formation. In 1988, it became the state fossil of Utah: more than 60 *Allosaurus* skeletons, ranging from juveniles to adults, are known from this state. This speciesis the most common large theropod in the Morrison Formation, accounting for 70–75% of theropod specimens (Fig. 5). The best known *Allosaurus* was Big Al, made famous by the television series *Walking with Dinosaurs* in 2000. Al's skeleton has 19 injuries, including a badly infected toe (Fig. 6).

Ceratosaurus could reach 6 metres long. It had a horn on its nose that might have been for display and would have been brightly coloured. This species had some of the largest tooth-to-body ratios of any theropod and, interestingly, it had a long, flexible body, with a deep tail shaped like that of a crocodilian. Palaeontologist Robert Bakker has suggested that *Ceratosaurus* could have hunted aquatic prey such as fish and crocodiles (Fig. 7).

The megalosaur predator *Torvosaurus* is known from a series of incomplete specimens, so was probably much rarer than *Allosaurus*, although it was around the same size, at 9 metres long. The species *Torvosaurus gurneyi*, discovered in Portugal, is the largest theropod known from Europe, at 11 metres long.

Comparison with the Tendaguru Formation:

The Tendaguru Formation in Tanzania, containing the richest deposits of late Jurassic Africa, is comparable to the Morrison because the sites date to the same period and have a similar range of dinosaurs. For example, the Morrison's *Brachiosaurus* and *Stegosaurus* would have occupied the same ecological niches as *Giraffatitan* and *Kentrosaurus* in the Tendaguru. *Allosaurus* is known from both formations but is much rarer in Africa.

A noticeable difference between the two sites is the depositional environment. Whereas the rocks of the Morrison Formation were deposited in a terrestrial basin, the Tendaguru Formation has some marine strata. As a result, the Tendaguru contains marine organisms such as ammonites, corals and other inhabitants of a shallow sea.

Conclusions:

The Morrison gives a remarkable insight into late Jurassic ecosystems, including not only some of the largest dinosaurs of all time, but also animals that existed alongside them. Specimens from the Morrison Formation can be seen in museums all over the world, such as the Natural History Museum in London, the American Museum of Natural History in New York City and the Royal Ontario Museum in Toronto, Canada.

Suggestions for further reading:

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[1]Camborne School of Mines, University of Exeter, UK.