# NORTH DAKOTA'S MOSASAUR

BY CLINT A. BOYD

October is a time of ghosts and ghouls, costumed creatures, and malevolent monsters. This year the paleontology team at the North Dakota Geological Survey fully embraced the spirit of Halloween, introducing the world to a never-before-seen sea monster that terrorized the Western Interior Seaway of North Dakota 80 million years ago during the Cretaceous Period. On October 30th, after eight years of hard work, a new species of mosasaur that first emerged from the black shale of the Pembina Gorge in 2015 was named: *Jormungandr walhallaensis* (Zietlow et al., 2023).

## AN IMPORTANT TRANSITIONAL SPECIES

Mosasaurs were aquatic reptiles that lived mostly in marine environments during the Cretaceous Period, including the Western Interior Seaway that once covered most of North Dakota. They were the apex predators of their time, with some reaching lengths in excess of 40 feet. The specimen recovered from the Pembina Gorge was from an animal approximately 24 feet in length, which is still an impressive-sized animal (see cover image). They were fully adapted to their aquatic lifestyle, with large flippers on the front and hind legs and most species likely had a fluke on the tail. However, like modern whales and other aquatic mammals, they had to return to the surface in order to breathe. They had finely patterned scaly skin and likely did not lay eggs like many other reptiles; instead, they gave birth to live young in the open ocean (Field et al., 2015).

We previously reported on the discovery of this new species of mosasaur and the initial fieldwork focused on recovering the animal in a newsletter article in January 2017 (Boyd, 2017). It was clear at that time that the partial skeleton that was discovered in 2015 was a new species, but at that point, only a small portion of the specimen was fully cleaned. As work on the specimen progressed over the years, it became clear to us that this specimen was more unique than we originally suspected. In the 2017 article, I suggested it may represent a new species of the genus *Mosasaurus*, but as additional bones were exposed it became clear this specimen didn't conform with any currently described genus. The quadrate, which forms the outer portion of the ear and the jaw joint, closely resembles *Mosasaurus*, but the jaws and the skull roof more closely resemble the smaller and slightly older genus *Clidastes*. We had a bit of a conundrum on our hands!

**FIGURE 1.**
Photograph of the first Public Fossil Dig event in August of 2000 in the Pembina Gorge State Recreation Area. Participants are working along a continuous fossil layer in the Pierre Formation immediately adjacent to the road.

**FIGURE 2.**
NDGS paleontologists Clint Boyd (left), Becky Barnes (middle), and Jeff Person (right) removing plaster jackets containing the skull of the newly named mosasaur *Jormungandr walhallaensis* during the Public Fossil Dig in the Pembina Gorge State Recreation Area in 2015. Note the position of the quarry above the road surface (upper left). Photograph by Sean Ternes.

To help solve this riddle, we brought in two outside researchers with extensive knowledge of mosasaur anatomy and relationships: Amelia Zietlow and Nathan Van Vranken. Nathan is a member of the faculty at Eastern West Virginia Community and Technical College and has worked with our team previously to describe the first mosasaur fossils collected from the Breien Member of the Hell Creek Formation in North Dakota (Van Vranken and Boyd, 2021). Amelia is a student studying mosasaurs at the Richard Gilder Graduate School at the American Museum of Natural History. Together, we set to work examining the new mosasaur's bones and comparing them to known species. After months of research, it was clear that this new species was indeed intermediate between *Mosasaurus* and *Clidastes*, providing new information on the evolution of these mosasaurs. The transitional nature of this specimen fits with the age of the specimen, which comes from the middle Campanian (~80 mya) Pembina Member of the Pierre Shale Formation. *Clidastes* is most commonly recovered from older rocks, and last appears in the middle Campanian. Alternatively, Mosasaurus first appears in the upper Campanian and persists into the Maastrichtian, going extinct at the end of the Cretaceous Period.

## CONSTRUCTING THE NAME

Species names have two parts that are always used together. The first word is the name of the genus, and the second word is the species epithet. For example, in the dinosaur *Tyrannosaurus rex*, *Tyrannosaurus* is the genus and rex is the species epithet. Very early in my work on this specimen, I decided that if it was a new species the species epithet should reflect the region it came from in North Dakota. When we are conducting fieldwork in the Pembina Gorge each summer we stay in the city of Walhalla, and we have grown very fond of the area and the people that live there. So, I decided the species epithet should honor the city. When you form a species epithet in reference to a geographic location you add the suffix -ensis at the end of the name, so a species named after Walhalla becomes walhallaensis. As research on the specimen continued and it became clear that it represented a new genus as well, I tried to think of a name that would work well with the species name. Given the similarity of spelling between Walhalla and the mythological Norse location Valhalla, we chose to name it after the legendary sea-dwelling World Serpent: *Jormungandr*. The resulting name, *Jormungandr walhallaensis*, honors both the region in which it was discovered and the Scandinavian heritage of many who currently call the area home.

## IMPORTANCE OF EXCAVATION

This discovery highlights the importance of the work done by NDGS paleontologists to protect and preserve North Dakota's prehistoric heritage, often through our Public Fossil Digs program. The first ever NDGS public fossil dig was held in the Pembina Gorge in 2000 in the same area where this new mosasaur would eventually be discovered (fig. 1). That work was prompted by the need to continually cut back the uphill slope along an important road running through the Pembina Gorge State Recreation Area. Throughout the Pembina Gorge, the soft rocks of the Pierre Formation are steadily eroding and slumping off the steep walls of the gorge and into the river below. As a result, the road at this location must be moved over a few feet every few years as the rock beneath it slumps away. These actively eroding hillsides are great places to find fossils, and at the site of our fossil dig there are an exceptionally high number of fossils present. These fossils would quickly be lost, either to natural erosion or to construction work on the road, if we were not actively working to collect and preserve them. As a result, our work in the Pembina Gorge is a constant race to discover and remove all the fossils we can each summer so that the road can remain open.

When we first started work on this specimen in 2015, the location that would eventually become the *Jormungandr* quarry was about 15 feet off of the road and 15-20 feet above the road surface (fig. 2). We actively worked that quarry from 2015 through 2018, when we recovered the last of the specimen and moved to another location on the

**FIGURE 3.**
Panoramic photograph of the outcrop of the Pierre Formation along the newly rebuilt road through the Pembina Gorge State Recreation Area shortly after construction was completed. The white dashed line highlights the current position of the old back wall of the quarry where *Jormungandr walhallaensis* was collected. Photograph by Clint Boyd.

hillside. Over the years the rocks in this area have slid down so that the quarry is now only about 10 feet or so above the road. In the summer of 2022, a large area of rock downslope from the road failed and slumped away, requiring the road to be closed until work could be completed to remove several feet of the rock uphill from the road and shift the entire road surface over away from the edge of the gorge. The required work was so extensive that the entirety of the hillside where the quarry was located was removed, with only the very back wall of the quarry now visible (fig. 3). If we had not discovered this specimen years earlier and had the time to fully collect it, this scientifically important specimen would have been lost over the side of the hill during this construction work. This is the exact reason why we return to the Pembina Gorge each summer to scour this hillside for fossils: every discovery is time-sensitive and needs to be acted on immediately or be lost forever.

## REBUILDING A SEA MONSTER

This mosasaur specimen provided a unique opportunity to understand mosasaur anatomy. Many mosasaur specimens are found with their skull bones still connected in life position, often squashed or flattened into a single layer. In those cases, only some of the bone surfaces can be observed, while others are covered or completely obscured by other bones. The skull of *Jormungandr* is preserved disarticulated, with nearly all of the skull bones separated from the others, allowing all surfaces to be examined. We quickly realized that this style of preservation provided us with a unique opportunity to produce a detailed, fully figured description of mosasaur skull bones that would be extremely helpful to other researchers in identifying mosasaur bones from other sites. But as we moved forward with our work on the specimen, we quickly encountered a few problems.

The first problem is that the bones are bright white in color and are fossilized in part by reflective gypsum minerals, making them difficult to properly photograph. Second, many of the bones have deep folds and grooves, making it difficult to get the entire bone surface into focus in a single image. The final, and biggest, problem is that the bones are very fragile, making them difficult to handle or position in the correct view without damaging them. The solution to these problems was to employ a high-tech solution: 3D scanning. Using an Einscan-SP scanner and an automated turn table, we were able to produce 3D models of every bone we have from Jormungandr. Once a model of a bone was finished, it could be rotated and artificially lit in any view we needed to figure with no risk of harm to the fossil (fig. 4).

Another benefit of scanning all of the bones is that we could load them all into a program and reassemble them into life position, producing an accurate model of how Jormungandr's skull would have looked in life. In cases where we only had a bone from one side of the skull preserved, we were able to mirror image the model and use it to replace the missing bone on the other side. Using

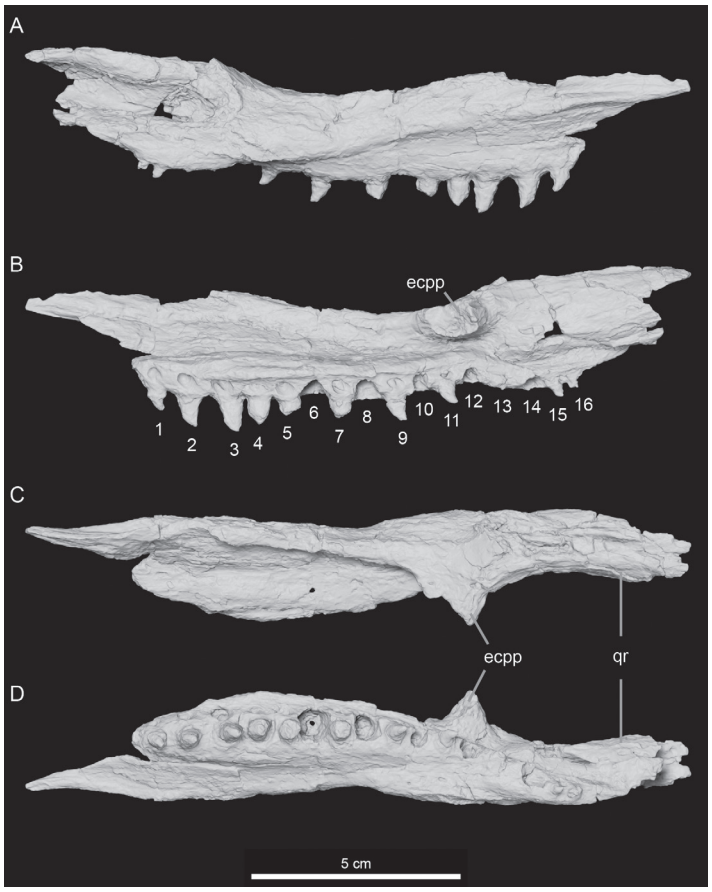


**FIGURE 4.**
3D model of the left pterygoid of NDGS 10838, the holotype of *Jormungandr walhallaensis*, shown in medial **(A)**, lateral **(B)**, dorsal **(C)**, and ventral **(D)** views. In **(B)**, tooth positions are numbered. Abbreviations: ecpp, ectopterygoid process; qr, quadratic ramus. Figure modified from Zietlow et al. (2023: fig. 28).

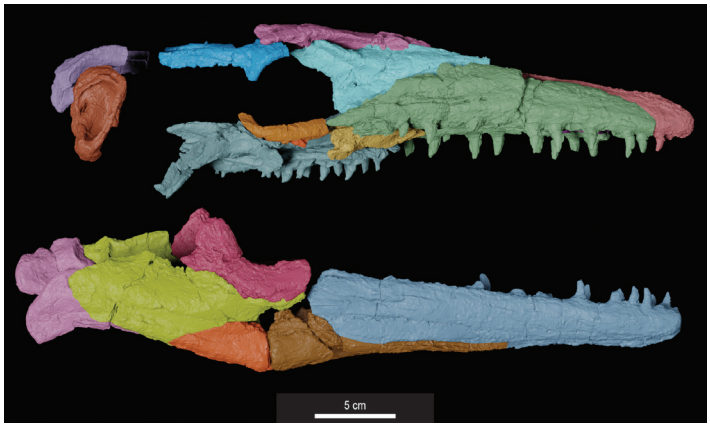


**FIGURE 5.**
Reconstructed model of the skull of *Jormungandr walhallaensis* shown in right lateral view. The skull was digitally assembled using 3D scans of the real bones. Any bones not preserved in this specimen are not present in this reconstruction. Model constructed by Amelia Zietlow.

those methods, lead author Amelia Zietlow was able to reconstruct most of the skull; however, some portions of the skull, including the braincase, were completely missing from the specimen (fig. 5). To address that problem, we partnered with paleontological exhibits company Triebold Paleontology Inc. They had models of the bones we were missing from closely related mosasaur species

**FIGURE 6.**
3D printed cast of the reconstructed skull of *Jormungandr walhallaensis* shown in right lateral view. Triebold Paleontology Inc. filled in any missing bones using data from closely related species, printed the finished model on a resin printer, painted the cast to match the color and texture of the original bones, and built the metal armature to hold the specimen. This skull is now on display at the Walhalla Public Library. Photograph by Clint Boyd.

that they used to fill in the rest of the skull, completing the model. They then 3D printed the skull on a large format resin printer and painted it to resemble the original fossils (fig. 6).

## NEW EXHIBIT

Once our research was finished and we had confirmed that the Pembina Mosasaur is a new species, we wanted to set up an exhibit in the local area so that people in that area could learn about the unique mosasaur that is currently only known from the rocks exposed in the Pembina Gorge. Our work in that area is based out of the town of Walhalla, and we already have an exhibit in the Walhalla Public Library that includes the first mosasaur fossils the North Dakota Geological Survey collected from the Pembina Gorge over 20 years ago. We talked with the librarians and came up with a plan to commission a cartoon-styled mural for the children's area of the library (fig. 7) and provide a cast of Jormungandr's skull, along with casts of other fossils found in the Pembina Gorge. The casts were delivered to the library in June, but installation of the mural was delayed while some repair work was done on the ceiling in the area where it will be installed. This new exhibit adds to our array of over two dozen fossil exhibits across North Dakota that represent our commitment to exhibiting the best fossils North Dakota has to offer in the local area whenever possible (Barnes and Boyd, 2022).

## MORE YET TO COME

The publication of *Jormungandr walhallaensis* is the culmination of a lot of work by paleontologists here at the North Dakota Geological Survey and the outside researchers that collaborated in this study. The result is the first new mosasaur species named from North Dakota, providing recognition of the rich fossil record of these animals preserved in our state. But while *Jormungandr* is North Dakota's first named mosasaur, it is unlikely to be the last. The well-preserved mosasaur skeleton previously collected outside of Cooperstown in Griggs County (Hoganson et al., 1996) and an impressively large mosasaur skeleton collected near McCanna in Grand Forks County (Hoganson, 2014) are currently under study and either, or both, may represent previously unknown species. Additionally, we have multiple other mosasaur specimens from the Pembina Gorge that are clearly not the same species as *Jormungandr walhallaensis* that we are working to identify. Thus, the description of *Jormungandr walhallaensis* marks the very beginning of our work on North Dakota's mosasaurs.

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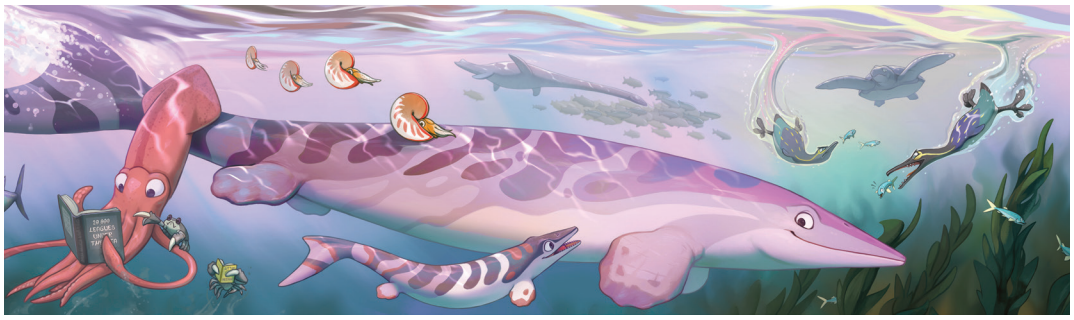

**FIGURE 7.**
Mural created for the Walhalla Public Library for the new exhibit installed in the kids' reading area depicting a cartoon version of the fauna of the Western Interior Seaway as preserved in the Pierre Formation that crops out in the local area. The mosasaur *Jormungandr walhallaensis* is the centerpiece of the mural. Art by Karolina Twardosz.