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COLLECTING THE WORLD'S LARGEST KNOWN DINOSAUR SKULL

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Abstract—Excavating and transporting fossils from the field to a laboratory for preparation requires significant skill, care, and engineering, especially when dealing with large specimens. While the techniques for collecting fossils by applying jackets haven't changed much since they were first used in the 19th century (Davidson and Everhart, 2017), only limited literature is available on the methods necessary to extract large and heavy fossil megablock jackets. Here we describe the techniques employed to collect a jacket containing the largest known dinosaur skull from a site west of Cuba, New Mexico. The jacket weighed approximately 15,000 lbs (6,800 kg), measured 12.0 feet (3.7 m) long by 8.0 feet (2.4 m) wide, and was 2.0 feet (0.6 m) thick. The specimen is housed in the Museum of Evolution collection near the town of Maribo in Lolland, Denmark, and a cast is on display at the University of New Mexico Silver Family Geology Museum in Albuquerque, New Mexico.

INTRODUCTION

The San Juan Basin in northwestern New Mexico is well known for its Late Cretaceous rock units that are rich in dinosaur fossils (Lucas and Heckert, 2000). Since 1885, dinosaur fossils have been collected in the basin's Fruitland, Kirtland, and Ojo Alamo Formations. Most fossil collection efforts have taken place in the northwestern part of the basin, whereas the eastern San Juan Basin has received comparatively little attention from Cretaceous dinosaur workers.

In 2021, the authors of this paper secured the fossil rights to a private ranch in the southeastern part of the basin near Cuba, New Mexico. This area was pursued based on geological surveys that indicated that there were significant outcrops of the Late Cretaceous Fruitland and Kirtland Formations, suggesting a high potential for discovering dinosaur fossils. The owner of the private ranch informed the authors of a site mapped as the Late Cretaceous (Campanian) Kirtland Formation where dinosaur bones had previously been found by dinosaur hunter Mark Eatman, but not thoroughly investigated.

At this site, the authors uncovered an approximately 60% complete postcranial skeleton and an approximately 80% complete skull of an exceptionally large ceratopsian dinosaur, *Torosaurus* sp. (Fig. 1). Standard-sized plaster jackets were constructed for all the postcranial elements, but to ensure the skull remained intact during transport to the laboratory for preparation, a megablock jacket needed to be constructed.

PREJACKET

The skull measured approximately 10.2 feet (3.1 m) long and 7 feet (2.13 m) wide and was preserved face down in mudstone. It was oriented roughly north–south, with the rostrum facing north and the back end of the frill facing south. The authors took care to uncover only as much of the skull as was necessary to understand the extent of the bone in the field, as fine preparation is best carried out under laboratory conditions (Fig. 2). Awls and screwdrivers were used to remove matrix from the bone, and an approximately 10% solution of Paraloid B-72 in acetone was applied to the bone and matrix as a consolidant when needed. An approximately 6-inch (15-cm) halo of matrix was left around the bone whenever possible to reduce the risk of the bone crumbling or coming into contact with plaster.

After the authors were confident that they understood the full extent of the skull, they applied a thick layer of wet packing paper separator to all of the exposed bone. A plaster "cap" was then applied to the paper using strips of burlap in various sizes coated in Hydrocal White plaster mixed with water to a consistency similar to pancake batter. This was done to protect

Figure 1. Kellach and Orin Suazo admiring the left squamosal of the *Torosaurus* sp. skull early in the excavation.

Figure 2. Thomas Suazo with the defined *Torosaurus* sp. skull block before the plaster cap was applied.

the skull from the elements and from workers inadvertently coming into contact with it while the jacket was being trenched and pedestaled.

An approximately 3.0-ft (0.9-m)-deep trench was dug around the entire skull using hand tools, along with a drainage ditch on the downhill slope side in case of rain. During the trenching process, it was discovered that a several-foot-thick sandstone lay beneath the mudstone where the skull was preserved. The authors decided to jacket in a portion of the sandstone to prevent the friable mudstone from dumping out as the jacket was cracked and flipped for removal.

CONSTRUCTING THE JACKET

Due to the large size of the skull block, an exceptionally thick and strong jacket was necessary. More than 20 layers of Hydrocal White-soaked burlap were applied to the entire pedestaled skull block. Typical fossils jackets require between 3 and 10 layers, so the authors felt confident that 20 layers would be adequate to ensure that the jacket would not flex or crack during removal or transport. After the top and sides were jacketed, the process of undercutting the block began. It was decided to create a centered east–west tunnel beneath the skull block and apply plaster and burlap underneath the jacket (Fig. 3). Gravity made it challenging to adhere the burlap to the underside of the jacket, but priming the area with a thin layer of wet plaster and using relatively small pieces of burlap, approximately 8 inches (20 cm) by 8 inches (20 cm), soaked in plaster helped it to stick better. The finished pedestaled skull block measured approximately 12 feet (3.7 m) long by 8 feet (2.4 m) wide and was 2 feet (0.6 m) thick.

PREPARING TO FLIP THE MEGABLOCK

The authors extensively reviewed existing literature and online sources for examples of megablock removals. The best-documented megablock removal was the *Utahraptor* block from a cliff near the town of Moab, Utah. Although there is no formal literature detailing the methods used, the authors found photos and brief descriptions of the process on social media that are now viewable at the Utahraptor Megablock Fossil Project website (Utah Geological Survey, 2024). For the *Utahraptor* block, workers built a sled beneath the jacket and used an excavator to drag it out. The absence of formal documentation regarding fossil megablock removal techniques motivated the writing of this paper.

It was decided that the best method to remove the megablock was to construct a wooden sled on the top of the jacket, flip the block directly onto the sled using a telescopic handler, and then winch it onto a tow truck. The authors opted against building a sled underneath the jacket, as was done with the *Utahraptor* block. That approach would have required backfilling the existing tunnel with wood or rock and excavating out the two remaining sandstone pedestals. Doing so would have made it necessary to work underneath the block, which posed a significant risk due to the weight of the block being supported only by backfill. The authors deemed the risk too high to proceed with this method.

ESTIMATING THE WEIGHT OF THE MEGABLOCK

To estimate the weight of the megablock, the authors multiplied its approximate volume by its approximate density. They began by weighing a roughly 2-inch (5.1 cm) cube of mudstone matrix using a digital scale. To determine the cube's volume, the authors submerged it in a 100 ml graduated cylinder that initially contained 50 ml of water. They subtracted the initial 50 ml from the final measurement to find the volume.

Next, they calculated density (D) by dividing the weight (M) in grams by the volume (V):

$$D = M / V$$

Using the calculated density (D), they multiplied it by the estimated volume of the jacket (V) to obtain the weight of the jacket (M):

$$M = D * V$$

Based on upper and lower estimates of the jacket's volume (3.0 m^3 and 2.3 m^3, respectively) and density (3,000 kg/m^3 and 2,400 kg/m^3, respectively), and considering the minimal differences in density among mudstone, sandstone, and burlap and plaster, the authors estimated a weight range of 5,520 kg (12,100 lbs) to 9,000 kg (19,800 lbs). The median estimates of the jacket's volume of 2.6 m^3 and density yielded a median calculated weight of 7,020 kg (15,400 lbs). Precise measurement of the jacket's volume was impossible due to its irregular shape and size.

CONSTRUCTING THE SLED

Four yellow pine rungs, each measuring 6 inches (15 cm) by 8 inches (20 cm), were evenly spaced and attached across the width of the jacket using plaster and burlap to keep them in place (Fig. 4). The rungs were trimmed to be roughly the same width as the jacket. Two 6-inch (15-cm) by 6-inch (15-cm) yellow pine skis, each 12 feet (3.7 m) long (Fig. 4), were

Figure 3. Side view of the megablock jacket. Note the tunnel through the center and the two remaining sandstone pedestals supporting the weight of the jacket.

Figure 4. Wooden sled construction and ratchet straps.

attached perpendicular to the rungs using 10-inch (25-cm) lag bolts. For added strength, two 6-inch (15-cm) by 6-inch (15-cm) yellow pine crossbars were bolted in between the skis (Fig. 4). To provide even further stability, four heavy-duty ratchet straps—one on each end and two running through the tunnel—were used. Shallow grooves (Fig. 4) were cut into the skis for the ratchet straps to sit into, allowing the jacket to slide onto the transport trailer unobstructed.

MACHINE USED TO FLIP

The authors rented a 2020 Gehl DL12-55 Telescopic Handler (Fig. 5) with a rated lift capacity of 12,000 lbs (5,440 kg), which was the highest lift capacity of all rentable telescopic handlers. Since the full weight of the jacket would not need to be lifted for it to pivot and flip over, the authors concluded that the lift capacity of the telescopic handler would likely be sufficient. The machine was rented from H&E Equipment Rentals in Albuquerque, New Mexico, and was delivered to the site. An operator was hired to run the handler.

Figure 5. 2020 Gehl DL12-55 Telescopic Handler at the field site.

RIGGING

A steel spreader beam was attached to a hook on the telescopic handler's boom arm (Fig. 6) to distribute the weight of the jacket evenly. Two short lifting straps were hooked onto the spreader bars. Two heavy-duty tow straps were wrapped around the jacket through the tunnel, positioned perpendicular to the long axis, and connected to the lifting straps using bolt-type anchor shackles. The lift point on the tow strap was positioned low on the jacket, opposite the handler. To ensure that the jacket rested gently on the sled, an additional tow strap was looped through the tunnel and attached to a front-mounted Badland Apex truck winch with a 12,000-lb (5,440-kg) rating (Fig. 6), also positioned opposite the handler. The jacket was then cracked free of the remaining two pedestals using breaker bars and sledgehammers.

FLIPPING THE JACKET

The initial attempt to flip the jacket was unsuccessful because the weight was too much for the handler's fully extended boom arm (Fig. 7). The operator gently set the jacket back down, moved the machine closer, and shortened the boom arm. After adjusting the equipment, the operator lifted the jacket again (Fig. 8), elevating the side opposite the handler to a 90° angle by slowly raising and retracting the boom arm. At this point, a second operator applied tension to the truck-mounted winch (Fig. 8). As the jacket was lowered onto the sled, the winch operator gradually released the tension. The jacket safely came to rest on the sled (Fig. 9). The plaster jacket did not flex or crack during the flip, indicating that the more than 20 layers of plaster-soaked burlap applied were sufficient.

LOADING AND TRANSPORT

Anaya's Roadrunner Wrecker Service, of Santa Fe, New Mexico, was hired to load and transport the jacket from Cuba,

Figure 6. Steel spreader beam and front-mounted truck winch.

Figure 7. Initial unsuccessful lift attempt with telescopic handler boom arm fully extended.

Figure 8. Jacket being lowered down gently onto the sled.

New Mexico to the prep lab in Pleasant Grove, Utah. To load the jacket, a car hauler trailer with a tilting bed was positioned directly under the skis of the sled (Fig. 10). A chain was attached to the jacket behind the second rung and above the skis, and a winch mounted at the front of the trailer and another winch on the boom arm of the tow truck were used to pull it onto the trailer.

After loading, the jacket was driven to a flat area near the highway and transferred to a flatbed tow truck, which was more suitable for carrying the heavy load over a long distance (Fig. 11). The jacket was secured to the flatbed truck using heavy-duty ratchet straps. Anaya's Roadrunner Wrecker Service reported that the jacket weighed around 15,000 lbs (6,800 kg), indicating that the author's estimates were correct.

THINGS WE WOULD DO DIFFERENTLY

The skis of the sled measured 12 feet (3.7 m) in length, which were unnecessarily long. Their unsupported ends contributed to one cracking during the flip (Fig. 12). Thankfully, the crack was minor and didn't prevent the jacket from sliding on to the trailer. In hindsight, we recommend using more robust beams, measuring at least 6 inches (15 cm) by 8 inches (20 cm) for better support. A telescopic handler with a higher lifting capacity would have been beneficial, as the initial attempt at lifting the jacket with the boom arm fully extended was unsuccessful. Lastly, the car hauler trailer used to transport the jacket from the dig site to the highway was overloaded beyond its capacity. Selecting a trailer with a higher weight capacity would have been a safer choice for transporting the equipment, personnel, and specimen.

Figure 9. The jacket successfully flipped over.

Figure 10. Car hauler trailer tilting bed under the skis of the sled.

SAFETY

Safety was the top priority throughout the entire process. The decision to flip the jacket instead of constructing a sled beneath it was a responsible choice that minimized the time the authors spent underneath the jacket. It was crucial for everyone involved to maintain a safe distance when flipping a jacket. If the rigging failed or the jacket became compromised, there was a serious risk of injury or even death.

PREPARATION AND DISPLAY

Fossilogic, LLC in Pleasant Grove, Utah, carried out preparation of the specimen. The original skull (Fig. 13) and skeleton, along with a mounted cast (Fig. 14), are permanently displayed at the Museum of Evolution near the town of Maribo in Lolland, Denmark, and cataloged in their collection as EMK-0001. Additionally, the authors and landowners donated a cast of the skeleton to the University of New Mexico in Albuquerque, New Mexico, where it is exhibited in the Silver Family Geology Museum in Northrop Hall.

RESEARCH

Research and formal description of the *Torosaurus* sp. specimen is currently underway. The prepared skull measures 10.2 feet (3.1 m) in length, making it the largest measurable and intact dinosaur skull ever discovered. A *Pentaceratops* sp. skull cataloged as OMNH 10165 (Lehman, 1998) on display at the Sam Noble Museum of Natural History in Norman, Oklahoma, holds the Guinness World Record for the largest dinosaur skull at 10.5 feet (3.2 m) long. We do not consider this record valid since the length of its frill is almost entirely reconstructed (Fig. 15).

Figure 11. Jacket being transferred to the flatbed tow truck.

Figure 12. The red arrow points to the area where the unnecessarily long ski cracked.

Figure 13. *Torosaurus* sp. original skull, EMK-0001, on display at the Museum of Evolution, Denmark.

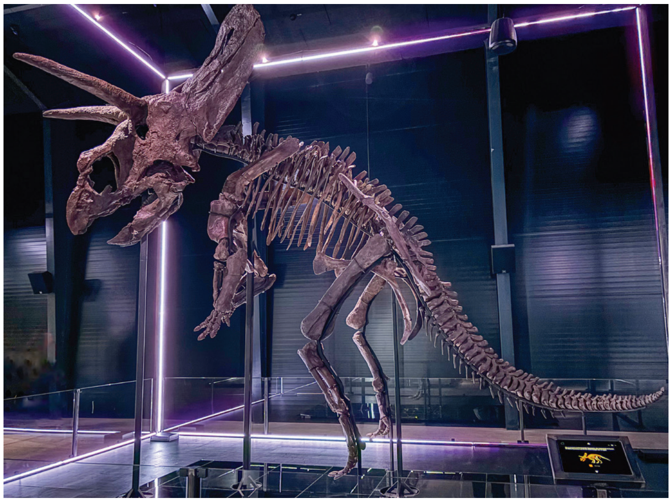

Figure 14. Mounted cast on display at the Museum of Evolution, Denmark.

CONCLUSION

We hope this manuscript serves as a valuable resource for those involved in collecting large and scientifically important fossils. Although the project presented challenges, constructing and extracting a megablock jacket proved to be the best method for safely collecting the exceptional *Torosaurus* sp. skull intact. The authors have reflected on aspects of the project that could have been improved. However, considering that the skull is now safely displayed and under study in a museum for the public to appreciate, we conclude that our collection strategy was successful. Workers involved in future projects similar to this must conduct thorough research and ensure that their planning is sound, but must also maintain flexibility. Mistakes could lead to irreparable damage to the specimen or even worse, cause injury or death to personnel.

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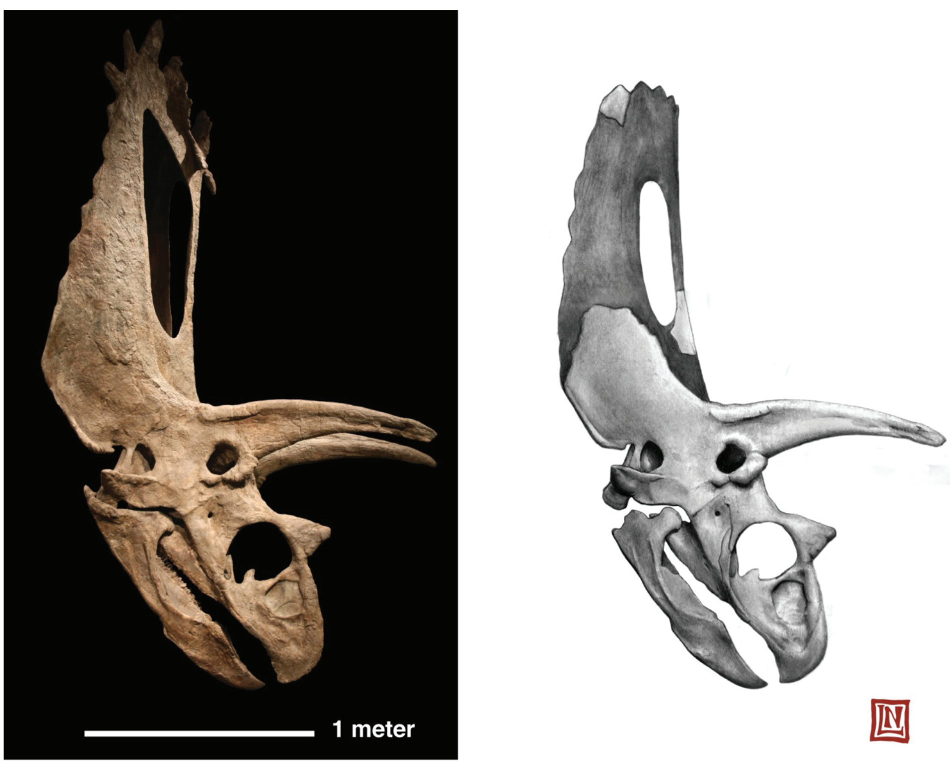

OMNH 10165, skull and illustration, showing reconstructed frill (in black). The hornlets on the back of the frill curve forward like in Pentaceratops, but this piece is plaster reconstruction- not real.

Figure 15. OMNH 10165 Reconstructed skull and illustrated areas of reconstruction (Longrich, 2011).

Interbedded sandstones, coals, and mudstones of the Mesaverde Group in a hogback roadcut along State Road 126 east of Cuba (mile 8.1 of Day 3 Road Log).