ASSESSING THE IDENTITY OF A NEW ALLOSAURUS SKELETON FROM THE JURASSIC MORRISON FORMATION OF WYOMING

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Background

The popular theropod dinosaur, *Allosaurus fragilis,* is known from numerous specimens discovered in Late Jurassic sediments across Montana, Utah, and Wyoming. Unlike many *Allosaurus* specimens, this isolated individual was discovered as an isolated, associated skeleton near Shell, WY in 2004 and preserves 65 cranial and postcranial elements.

This specimen exhibits a unique combination of large body size with sub-adult characteristics. Features such as lack of fusion between elements commonly fused in adults, such as the neural arches of the dorsal vertebrae, pubic boots, cranial elements, and pectoral girdle, suggest that this individual was not fully grown. Additionally, the number of alveoli in the dentaries and maxillae are higher than in "adult" individuals of *Allosaurus* (Madsen 1976). Despite these indications that the individual was not fully grown, it was comparable in body size to other, large "adult" *Allosaurus* specimens. Furthermore, this specimen exhibits variation described by Carpenter (2010) as not being associated with age, including on the skull elements such as the lacrimal.

Lacrimal

This specimen only preserves most of the right lacrimal (Figure 1). While the size of the lacrimal and the lacrimal horn has been found to be ontogenetic (Carpenter, 2010), the lacrimal of this specimen has a pronounced lacrimal horn, which has been reported to exhibit variation irrespective of ontogeny (Carpenter, 2010).

Comparisons with the lacrimals of other *Allosaurus* specimens, suggest this specimen is older individual due to the size of this element, and that it is part of the morphotype with a large lachrymal horn. Our specimen exhibits a posteriorly protruding curved ridge of rugose bone projecting into the orbit not previously described in other individuals by Madsen (1976), Carpenter (2010), and other comparative studies of *Allosaurus*.

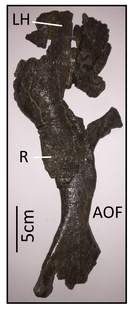

Figure 1: Right lacrimal, lateral view. Lacrimal Horn (LH), Ridge (R), and antorbial fenestra (AOF).

Vertebrae

This specimen preserves 19 vertebrae, including 4 cervical, the entire dorsum series, and one caudal vertebra. Each neural pedicle was examined and the degree of fusion with the centrum was determined. The majority of the dorsal vertebrae were not fully fused at time of death. This lack of fusion in the vertebral column is in contrast to the large size of this individual, supporting that this specimen was younger individual (Hone 2016).

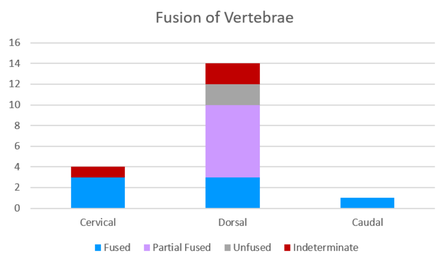

Figure 2: This graph summarizes the degree of fusion of the preserved vertebral column of this specimen. Above, (A) cervical 5, (B) dorsal 9, and (C) caudal vertebrae 13?.

Dentaries

The graph below plots the 44 *Allosaurus* dentaries examined by Madsen (1976) from the National History museum of Utah with the addition of this specimen. Tooth row was measured from the rostral edge of the first alveoli to the posterior edge of the last alveoli in millimeters, following Madsen (1976). Adult Allosaurs are described as having between 14-17 alveoli per dentary (Madsen 1976). In contrast, our specimen preserves 19 and 21 alveoli, left and right dentaries respectively, making this specimen more similar to those specimens labeled as unknown by Madsen (1976). The size of the dentary is considered ontogenetic (Carpenter 2010).

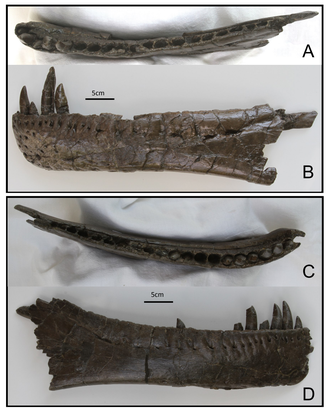

Figure 3: Left dentary in (A) ventral view and (B) lateral view. (C) Right dentary in ventral view and (D) lateral view.

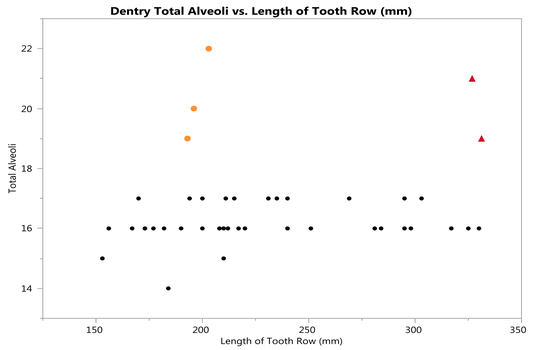

Figure 4: Total alveoli vs. length of tooth row for the right and left *Allosaurus* dentaries. *Allosaurus* specimens analyzed by Madsen, 1976 (Black circles), unidentified specimens labeled unidentified by Madsen (1976) (Orange circles), and our specimen (Red triangles).

Reconstructed Skull

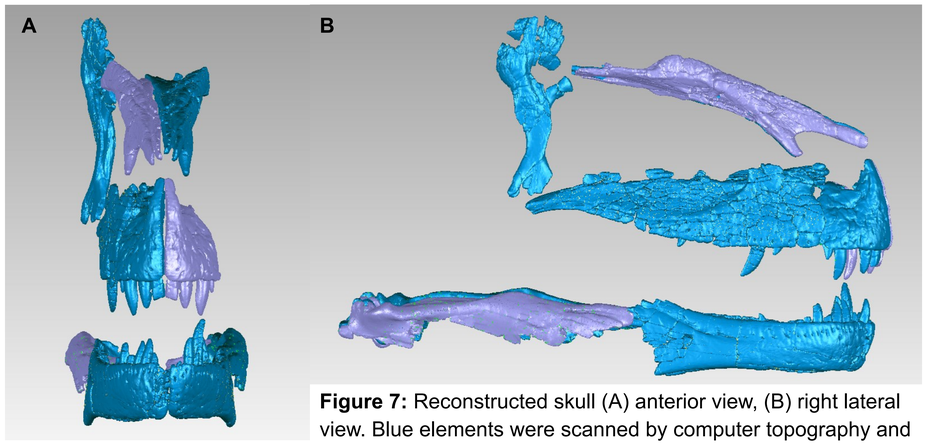

Figure 7: Reconstructed skull (A) anterior view, (B) right lateral view. Blue elements were scanned by computer topography and a 3D laser scanner. Purple elements have been mirrored.

Juvenile/Subadult or New Species?

Evidence for Juvenile/Subadult

- Lack of skeletal fusion: pectoral girdle, vertebrae, cranial elements, and pubic boots
- More gracile than robust femur
- General anatomical similarities to *Allosaurus fragilis*
- Features, such as 5 premaxillary teeth, support the genus *Allosaurus*

Evidence for Potential New Species

- Similar in size to an adult *Allosaurus*, while displaying skeletally immature characteristics
- Lacrimal exhibits an unique posteriorly protruding curved ridge of rugose bone projecting into the orbit
- Has higher total number of alveoli than other *Allosaurus*

Conclusion: TBD - Histological analyses are in progress, and will help these anatomical uncertainties

Maxillae

The graph below plots the 39 *Allosaurus* maxillae examined by Madsen (1976) from the National History museum of Utah with the addition of this specimen. Tooth row was measured from the rostral edge of the first alveoli to the posterior edge of the last alveoli in millimeters, following Madsen (1976). Allosaurs are described as having 15 - 16 teeth per maxilla, whereas the right maxilla of this specimen preserves 19 alveoli. Unfortunately the left maxilla is too incomplete to be included in this comparison.

Figure 5: Right maxilla (A) ventral view and (B) lateral view.

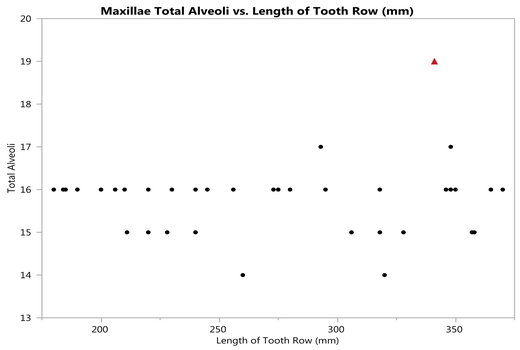

Figure 6: Total alveoli vs. length of tooth row for the right and left *Allosaurus* maxillae. *Allosaurus* specimens analyzed by Madsen, 1976 (Black circles) and our specimen (Red triangle).

Femur

The graph below is based on data collected by Madsen (1976) on 32 *Allosaurus* femora from the National History Museum of Utah. The femur of this specimen is incomplete preserving roughly half of its total length. The red square represents the predicted length of the femur of this specimen based on its mid-shaft circumference using the best-fit line (excluding our specimen). The red triangle represents this specimens estimated femur length is based on doubling the preserved length of the distal half of the femur. Though we acknowledge this is a rather rough estimation of femur length, it was preformed in order to explore the relative robusticity of the new specimen in comparison to previously described *Allsosaurus* femora. The gracile nature of this specimen is reflected in this graph by our estimated length without using the best-fit equation plotting below the best-fit line of other *Allosaurus* specimens and by the qualitative comparison of other skeletal elements, including the dentary.

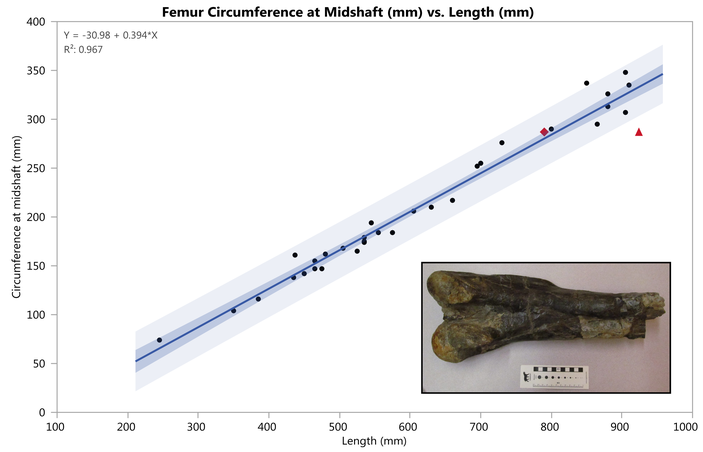

Figure 8: Femur Circumference at Mid-Shaft (mm) vs Total Length (mm). Individual specimens from Madsen, 1976 (Black circles), our predicted femur length using line-best-fit equation (Red square), estimated length based on doubling the preserved portion (Red triangle), best-fit line (blue), and shaded area represents a 95% confidence interval.

References & Acknowledgements

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