Campanian-Maastrichtian Ankylosaurs of West Texas

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Introduction

Big Bend National Park is known its unique dinosaurs, such as *Alamosaurus sanjuanensis* and *Quetzalcoatlus northropi*. Most major groups of dinosaurs are represented in the Late Cretaceous strata, which ranges from the Early Campanian through the Late Maastrichtian (approximately 17.6 Ma). However, one group of herbivorous dinosaurs, the armored ankylosaurs, have never been described in detail from this area. Fossil remains of these specimens are sparse and fragmentary; the only skeletal elements found in abundance are the dermal plates, known as osteoderms, that these dinosaurs utilized for defense. Previous studies have attempted to classify ankylosaurs down to the genus level by using thin sections to determine paleohistology. Using new microCT scanning techniques this study has attempted to classify the ankylosaur specimens found in this area so that the fossil record for the end of the Cretaceous in Big Bend can be completed.

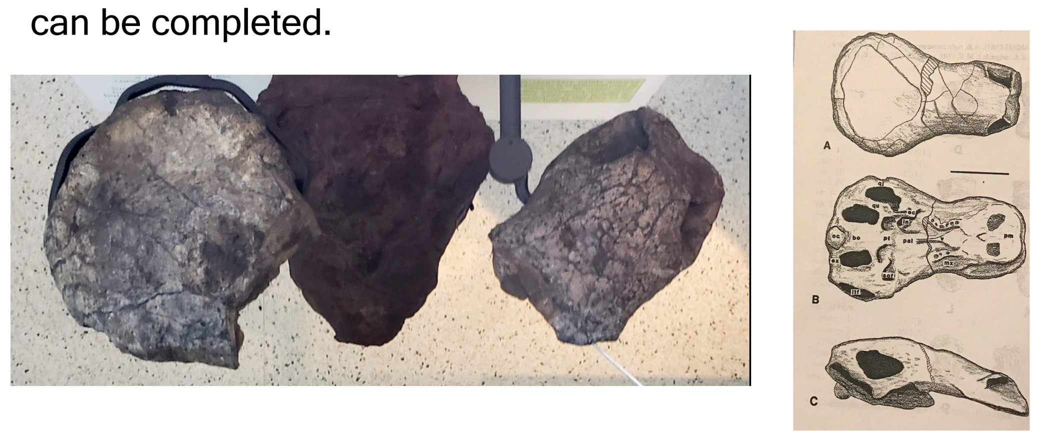

Figure 1. A dorsal view (right) and sketch (left, Carpenter 1990) of *Edmontonia longiceps* skull collected by Barnum Brown and R.T. Bird in 1940 from the Aguja Formation of Big Bend National Park.

Methods

To begin classifying the osteoderms from a standard osteological exam was done on two specimens from Big Bend National Park to determine overall morphology, external texture, and the distribution of vascular foramina and neurovascular grooves. Next, the osteoderms were scanned using microCT scanning facilities at the Vertebrate Paleontology Lab at the University of Texas at Austin. The osteoderms were scanned in transverse, dorsal, and left lateral view, creating sets of slices that were compiled as tiff files. The tiff files were then downloaded into the 3-D medical imaging software known as Dragonfly ORS. This allows the software to create a 3-D digital image of the osteoderms, which can be clipped to reveal the internal structures of the specimen. This approach is similar to using thin sections to study paleohistology without damaging the specimen, thus preserving it for later study.

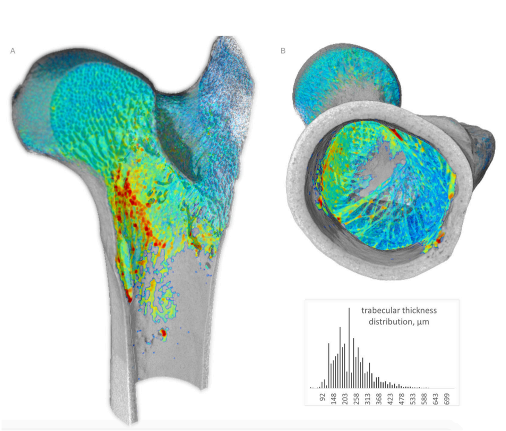

Figure 2. An example of Dragonfly ORS bone analyses feature being used to view the trabecular bone of a sheep femur.

TMM 31078-1 and TMM 45605-4 Comparison

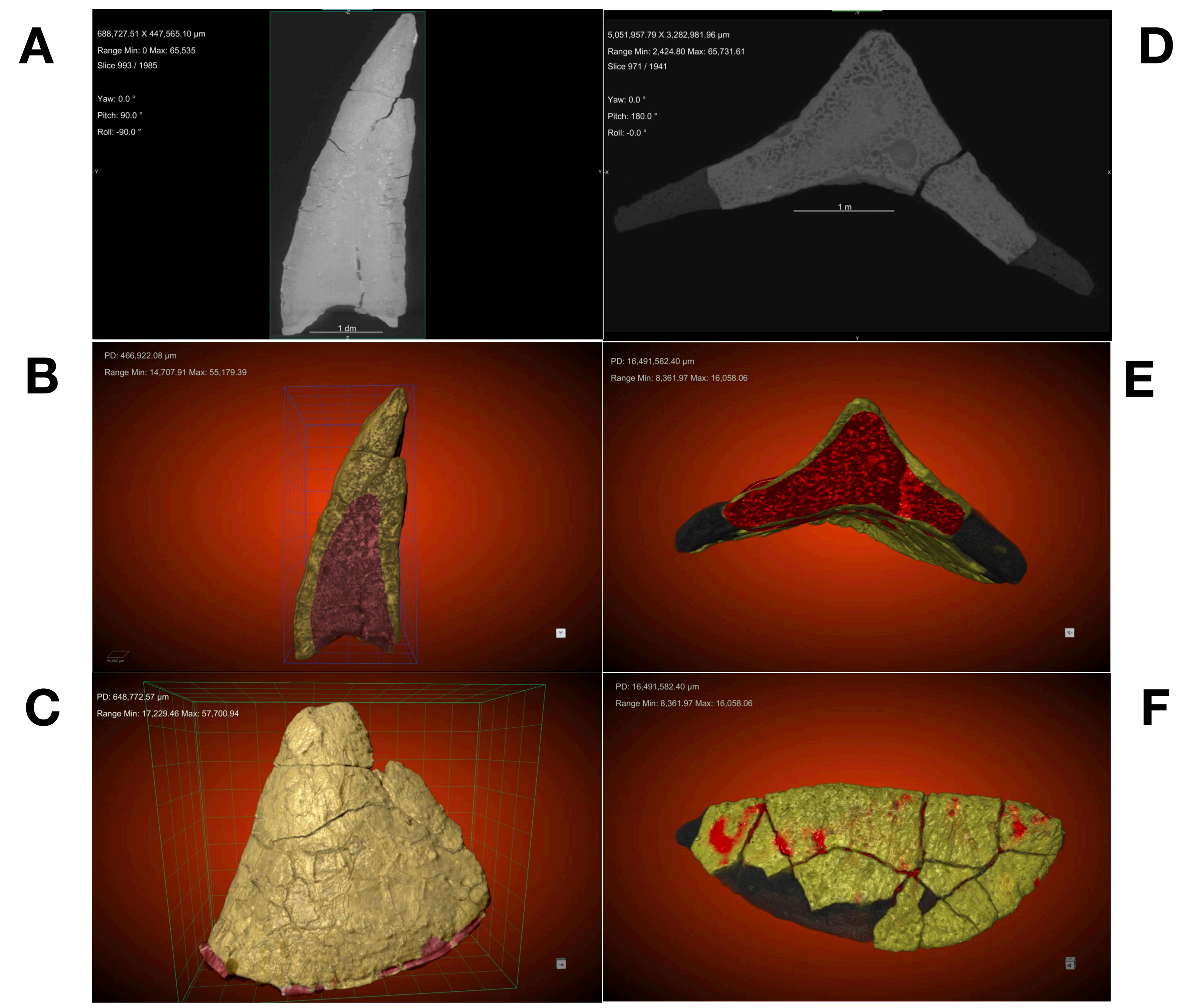

Figure 3. MicroCT scans of TMM 31078-1 and TMM 45605-1 along with digital 3-D models created using Dragonfly ORS.

Results

A microCT scan showing the transverse view of an ankylosaurid osteoderm (A) with a core of compact Haversian bone (18.7 ± 2% total thickness) with some cancellous bone in the apex left over from extensive remodeling. Here the external cortex is made up of cortical bone (12.3 ± 2% total thickness) which creates a well defined border between the cortex and the core. Using the 3-D bone segmentation feature it is observed that the basal cortex has been eroded away leaving core exposed at the concave base of the osteoderm (B). The osteological morphology of the osteoderm exhibits a circular base with an off-center apex (C). These features suggest that TMM 31078-1 is a distal thoracic osteoderm belonging to a derived ankylosaur (subgroup ankylosaurinae); the mostly likely taxa based on osteological morphology being *Euoplocephalus tutus* or *Ziapelta sanjaunensis.* A second osteoderm TMM 45605-4 (D) has been microCT scanned, and shows much different histologic characteristics than TMM 31078-1. This osteoderm retains its basal cortex (6.1% total thickness), however along with the external cortex (8.7% total thickness), are much thinner compared to the core which has a thickness of 85.2%. In addition, the core is not made of Haversion bone but cancellous trabecular bone. Within the core are vascular canals orientated perpendicular to the traverse plane, the largest being over 0.25 cm in diameter. The border between the cortical bone and trabecular bone is not well defined, at becomes difficult to separate cortical bone from individual trabeculae (E). It should be noted that the osteoderm was incomplete and had to be remodeled using putty. After using the bone segmentation feature it can be observed that the base of the osteoderm is flatter compared to TMM 31078-1, and that the over all the osteological morphology is more elongate and oval-like with a median keel . The external surface of the osteoderm shows profuse pitting around the keel, which becomes sparser along the right and left lateral flanks(F). These features suggest that this is a dorsal cervical osteoderm belonging to a member of the nodosauidae; given the elongate oval shape an the pitting along the keel the most likely taxon would be *Panoplosaurus mirus.*

Discussion

The results from the histologic and osteologic studies of TMM 310278-1 and TMM 45605-4 show that there are significant differences in the internal structure and morphology of ankylosaur osteoderms. Morphology of osteoderms can vary taxonomically and by bodily position as well; it should be noted that it has not been concessively proven that there is variation between the sexes. Histology can be used to determine which family of ankylosaurs the osteoderm came from, then the osteologic study of its morphology can be used to determine which genus (and in some cases taxon) the specimen belonged to. Therefore, it is important to determine the histologic characteristics, such as the relative thickness of the core and cortices and composition of the core is before studying the morphology of the specimen. The results of this study confirm previous work done by Scheyer and Sander (2004), Hayashi et al. (2010), and Burns and Currie (2014). However, in these studies thin section were used to determine the histologic characteristics, which is a method of destructive testing. Using microCT scanning the specimens are preserved, so that they can be of further use. Continuation of this study will yield more results, which should help complete the classification of ankylosaurs in Big Bend National Park. This will contribute to our understanding of the paleoecology of this area during the end of the Cretaceous.

Conclusion

MicroCT scanning is new, non-destructing method, of determining paleohistology and osteology. Since osteoderms are the most common fossils left behind from this group of dinosaur it is important to preserve them for future use. When studying members of the Ankylosauria this can be useful since certain histologic features are specific to each of the two families within this clade. Once familial relationships are determined osteology can be used to determine osteoderm morphology, which is specific to certain genera and subgroups.These methods will not only be of use in classifying ankylosaur specimens from Big Bend, but everywhere these dinosaurs are discovered.

Figure 4. An artist rendition of the nodosaurid Sauropelta (Carpenter 2012).