The Death of a Dinosaur:
What it reveals about a prehistoric environment

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Introduction

The Hell Creek Formation is located in the northern Great Plains, with outcrops in Montana, Wyoming, and North and South Dakota (Figure 1). This formation is approximately 70 to 100 meters thick and formed during the last 1.8 – 2.2 million years of the Cretaceous period, approximately 66 million years ago. The various types of sandstones and mudstones present here formed in a fluvial environment that consisted of various stream channels and floodplains. A wide variety of fossils can be found in Hell Creek Formation, including many species of fish, turtles, crocodilians, and even the last dinosaurs to inhabit this region [5].

The Hell Creek Formation is perhaps most well-known for its exceptionally preserved *Tyrannosaurus rex, Triceratops*, and *Edmontosaurus* fossils. *Edmontosaurus* was an herbivorous dinosaur belonging to the Hadrosauridae family. These dinosaurs existed during the upper Cretaceous period and went extinct during the end-Cretaceous extinction. An adult Edmontosaurus could be up to 12 meters (39 feet) long and weigh as much as 4 metric tons, and, to support its massive body, *Edmontosaurus* alternated between walking on two and four legs. *Edmontosaurus* was a very common dinosaur during the upper Cretaceous period, having been discovered throughout large portions of western North America. Specimens are often found in sediments that resemble fluvial environments, indicating that this dinosaur lived near bodies of water [3].

This study focuses on an assemblage of *Edmontosaurus* vertebrae discovered on the western side of a butte in the Hell Creek Formation, just outside of Marmarth, North Dakota. These vertebrae were buried in massive claystone deposits and were found close together but were not articulated. The arrangement of these vertebrae appears to follow a linear path oriented north-south; however, individual bones appear to show no preferred orientation. By evaluating the orientation of these vertebrae, we can gain insights about the kind depositional environment in which this dinosaur was buried.

Methodology

We began our investigation by numbering each of the hadrosaur vertebrae on site, and after all vertebrae were numbered, a grid was placed over the entire assemblage so that a map of their dispersal could be drawn (Figures 3 and 4). Sediment samples were collected from around the vertebrae before orientation data was taken. A vertebra consists of multiple processes, including the dorsal process and a single centrum, where the centrum is the center of the vertebra, and the processes are long portions of bone that protrude from it (Figure 2). Using a Brunton compass, we measured the orientation of the dorsal process in respect to the centrum by placing the compass parallel to the process and pointed away from the centrum. We recorded these orientations in azimuth notation and noted the direction of dip. Azimuth notation provides the horizontal direction that the bone is oriented in, ranging from 0°-360°, while dip direction indicates the direction in which the bones are plunging into the sediment. Using the directional data gathered in the field, the orientations of the vertebrae were plotted on a rose diagram for additional analysis (Figure 5). We also used Rayleigh's test for randomness to provide statistical evidence for trends in orientations [1].

By measuring the orientation of the dorsal process in reference to the centrum, we can estimate the velocity and direction of waterflow in a fluvial environment. Due to the natural shape of the vertebra, the large, spherical centrum acts as an anchor in the water while the narrow dorsal process acts as a rudder that gets pushed towards the direction of flow. In a higher velocity environment, such as a river, the vertebrae would likely be oriented in a similar direction, toward the direction of flow. However, in lower velocity environments, like in deltas and swamps, the orientations of the vertebrae would be more random since the water would not exert enough force to turn them [4]. Along with the orientations of the bones, the dispersal, or the distances between the individual vertebrae, was also noted. Dispersal begins with disarticulation, or separation of bones, and ends with the deposition of those bones; therefore, dispersal can give us insight into whether the bones were buried articulated (together) or disarticulated (separated). If the bones were buried in articulation, we would find them in close proximity to one another whereas if the bones were disarticulated, we would find them either in clusters with no directional trends or spread great distances apart [4].

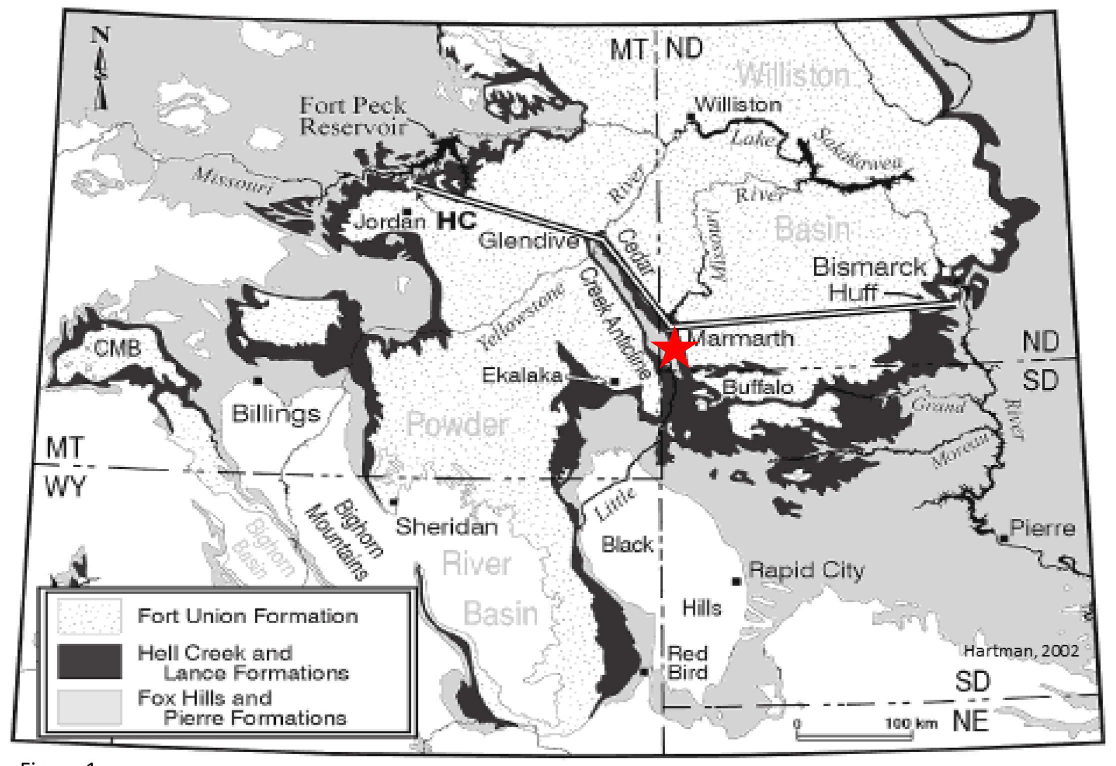

Figure 1

A map from Hartman et. al showing the extent of the Hell Creek Formation, spanning from central Montana and Wyoming to central North Dakota and northwestern South Dakota [2]. The red star marks the town of Marmarth, North Dakota where the *Edmontosaurus* vertebrae were discovered.

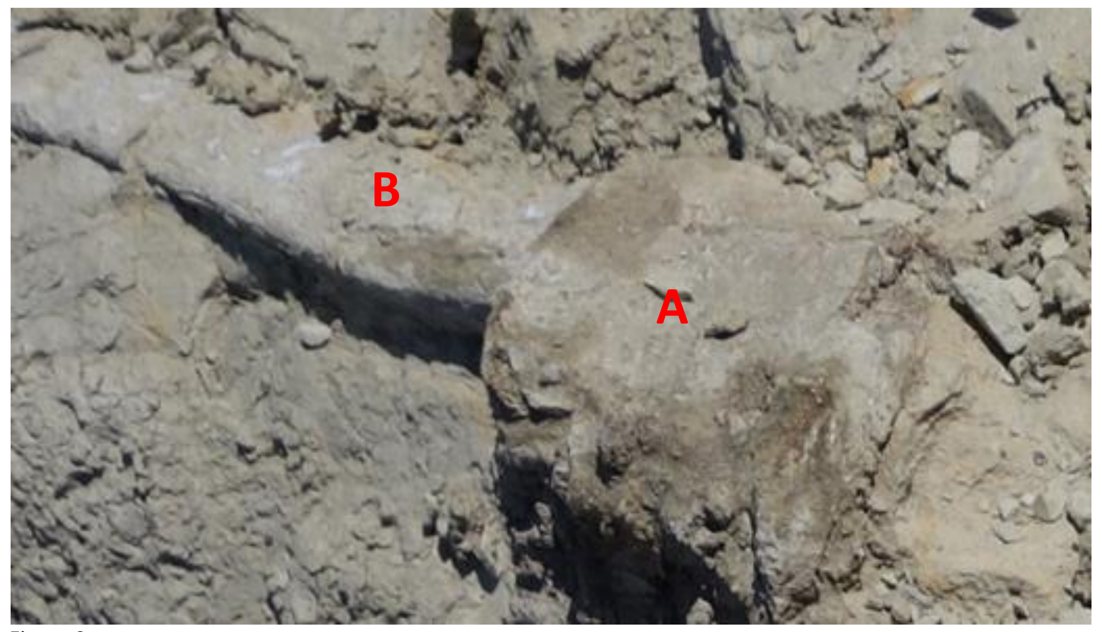

Figure 2

An *Edmontosaurus* vertebrae discovered in the Hell Creek Formation, ND. The centrum, labeled A, is the cylindrical part of the vertebrae. The dorsal process, labeled B, is the bone that protrudes from the centrum.

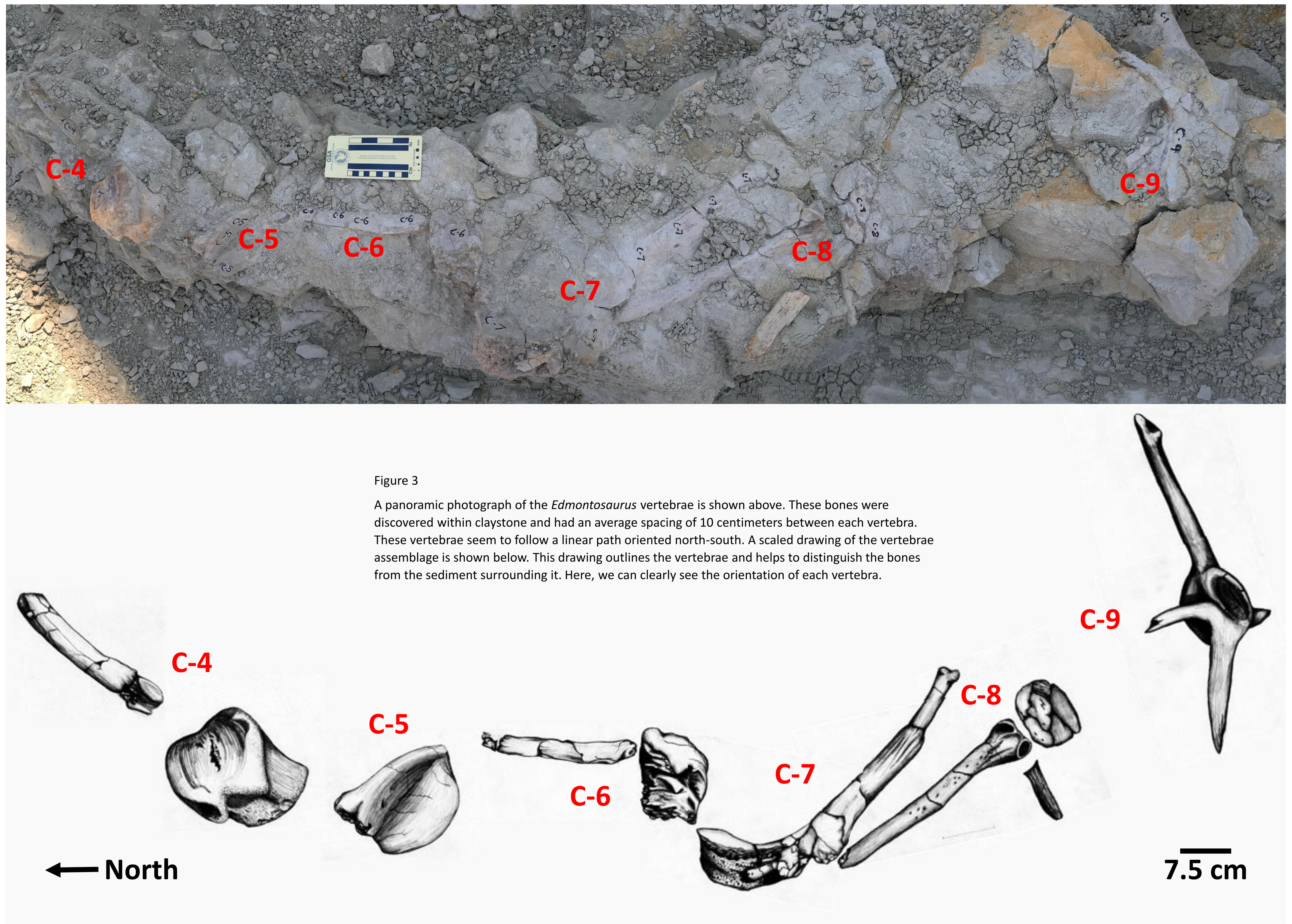

Figure 3

A panoramic photograph of the *Edmontosaurus* vertebrae is shown above. These bones were discovered within claystone and had an average spacing of 10 centimeters between each vertebra. These vertebrae seem to follow a linear path oriented north-south. A scaled drawing of the vertebrae assemblage is shown below. This drawing outlines the vertebrae and helps to distinguish the bones from the sediment surrounding it. Here, we can clearly see the orientation of each vertebra.

Figure 4

A team of geologists drawing a full-scale map of the vertebrae. This was done by carefully tracing the outline of each vertebra on a long, blank sheet of paper and later using this to make an accurate illustration of the entire assemblage, shown in Figure 3.

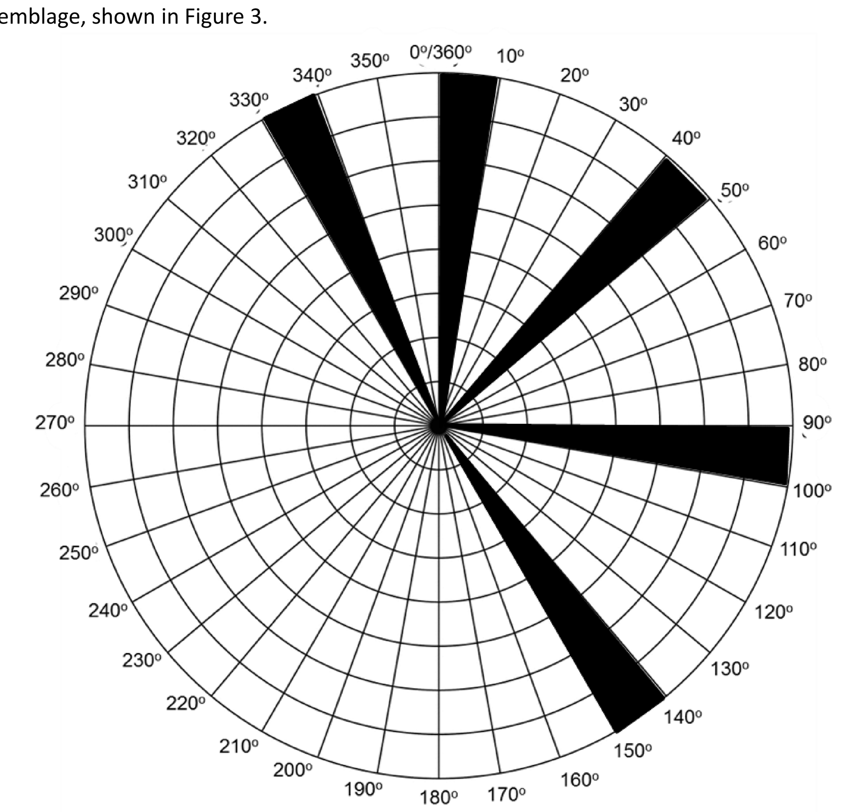

Figure 5

The azimuth orientations of the Edmontosaurus vertebrae plotted on a rose diagram. The shaded regions of the diagram represent the orientations of the process of each vertebra. The data appears to plot over a 180° arc.

Discussion

Our analysis of the environment in which these vertebrae were deposited is based on the sediment samples, dispersal of vertebrae, and orientation data collected. The sediment samples taken from around the vertebrae were determined to be claystone. Clay sediments are very small and are easily carried by water. In order for clay particles to settle, the velocity of the water needs to be slow, as in deltas and floodplains. Given that the vertebrae were found in massive claystone, it is possible that the vertebrae were deposited in a floodplain or delta environment.

The vertebrae studied were also found in very close proximity to each other. This indicates that the vertebrae were probably articulated during deposition and became disarticulated over time. In Figure 3, we see an average spacing of 10 cm between each vertebra. This shows that there was some dispersal, but not enough to indicate that they were disarticulated before deposition. If the bones were disarticulated before burial, they would be greater distances apart; whereas, if the vertebrae were semi-articulated, they would show some movement from water, but would remain intact because of lingering tissue connecting the bones. However, the distance the vertebrae are carried has a large influence on proximity. An assemblage of disarticulated vertebrae can remain close together if water velocity is slow, and they do not travel far. The topography of the land also influences deposition. For example, a meandering stream is likely to deposit sediment and bones along point-bars, but if this were the case, we would expect to find the vertebrae in coarse sediments, such as sand, not clay.

Initial observations of the orientation data plotted on the rose diagram seemed to indicate a slight directional trend (Figure 5). The azimuth values recorded in the field plotted across a 180° arc with no preferred direction, and the individual vertebrae deviated from their relative life position by no more than 90°. This pattern of dispersal may indicate that the vertebrae were deposited in a slow velocity environment, such as a delta or floodplain, which would not provide enough energy to rotate the vertebrae toward the general direction of flow. Raleigh's test for randomness also indicates that the vertebrae have a random distribution, which supports the hypothesis that the vertebrae were deposited in a slow velocity, fluvial environment, correlating again with the type of environment associated with our sediment samples.

Given our sediment samples, dispersal distance, and orientation data, we concluded that the vertebrae were likely semi-articulated during deposition and were likely deposited in a low velocity environment, such as a delta or floodplain. It is unlikely that there was enough water flow to orient the vertebrae in a specific direction because we would expect to find larger sediments surrounding the bones in a higher velocity environment. Any slight trends observed may be from low velocity water flow orienting larger bones over long periods of time. Although the water velocity would be too low to carry a large bone, such as a vertebra, it may have had enough energy to rotate it slightly as it rested on the bottom.

References

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