Experimental Study of Sediment Type and Organic Content on Fossil Trackway Preservation

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By

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ABSTRACT

The purpose of this study was to determine the effects of different sediment types on the preservation of footprints prior to fossilization. The sediments collected were an organic-poor sand, an organic-rich sand, an organic-poor clay, and an organic-rich clay. These sediments were chosen to mimic ephemerally wet siliciclastic environments similar to those of the Connecticut River Valley deposit (Newark Supergroup, Lower Jurassic). A pair of chicken feet was used to mimic the feet of a small theropod dinosaur. The sediments were separated into containers and allowed to sit to see if any significant microbial growth would develop within the sediments. Then chicken feet were used to create prints in the damp sediment. The footprints were repeatedly hydrated and desiccated until barely or no longer visible. Based on observations made of the footprints in varied sediment types, the clays were found to be better than sands at preserving the shapes of footprints over long periods of time and repeated wet-dry cycles. Organic-rich sediments were better than organic-poor sediments at preserving the footprints. Loss of some detail with each wet-dry cycle indicates that relatively rapid burial is necessary for fossilization of trackways in unconsolidated sediment.

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Introduction

A trace fossil is evidence of the activity of an ancient (pre-Holocene) organism. Some of the most recognizable trace fossils are footprints and trackways, especially those of the dinosaurs. Fossil trackways provide valuable information on the behavior of organisms such as speed, weight, and, in some cases, the presence of herd behavior (Alexander, 1989; Lockley, 1994). The actual methods by which trace fossils are preserved is incompletely understood. Some studies, such as those of Ahn and Babcock (2012) and Carvalho et al. (2013) suggest that sediment type, and particularly microbial components of sediment, play a major role in trace fossil preservation. One needs only to look at his or her own footprints left behind on a beach to see how unlikely such a thing is to last more than a few minutes, let alone millions of years, without some medium capable of retaining the integrity of the trace over a longer period of time.

Lower Jurassic deposits of the Newark Supergroup in the Connecticut River Valley are home to numerous footprints belonging to dinosaurs and other archosaurs (Olsen et al., 1998). The tracks were first discovered in the early 1800s and first studied by Edward Hitchcock (1836, 1858). Tracks were preserved primarily in siltstone and fine sandstone layers, which at the time of deposition were in an ephemerally wet non-marine environment. Many of the footprints are thought to have been left in river channel or lake-margin sediments (Lull, 1953).

This study was aimed at a better understanding of the conditions under which dinosaur footprints of the deposits such as the Connecticut River Valley (Newark Supergroup, Lower Jurassic) might have been preserved. In order to model the conditions under which the footprints were preserved, sediments were collected from similar Holocene environments and subjected to conditions presumed to be much like those of the Connecticut River Valley deposit. Footprints of a Holocene theropod (a chicken) were made artificially in sediments of various grain size and organic content, then subjected to alternating wet-dry cycles to assess their relative capacity for preservability.

METHODS

Fig. 1: Organic-rich sand prior to sampling.

Fig. 2: Organic-poor sand prior to sampling.

Fig. 3: Organic-growth clay prior to sampling.

Three types of sediment were initially collected and stored in glass jars: 1, sand with a high amount of organic material (Fig. 1); 2, sand with little organic material (Fig. 2); and 3, clay (Fig. 3). The sand samples were collected from the eastern beach of the Port Clinton Yacht Club, Lake Erie, Ohio. The clay was collected to the east of this location and further inland, Catawba Island, Ohio. Locations of the sediment samples are shown in Figure 4. Two samples of lake water were taken as well. One sample had a high amount of organic material (as visible through the glass jar), and the other sample had a lower amount of organic material. A pair of chicken feet (Fig. 5) was acquired to for purposes of forming footprints in sediment.

Fig. 4: Map showing the locations of the first three sediment samples.

Fig. 5: Chicken feet used to form footprints.

The sediments were separated into three plastic food containers and allowed to sit for a month in a well-lit room at room temperature to allow microorganisms in the sediments to grow and propagate. The sediment was hydrated using the lake water and then each type was separated into two containers. With the chicken feet, two prints were made in each of three containers (one of each sediment type), and sediment in the other three containers was left without footprints. The chicken feet were pressed into the sediment in a manner mimicking the motion of walking. The containers were left to sit for a few hours, after which all six had water added to them to simulate rising water. Enough water was added to the containers to almost completely submerge the sediment.

The containers were next observed twenty-four hours later and were allowed to completely desiccate over the course of a few days. The containers were then rehydrated and observed to determine how well footprints were retained. This protocol was repeated until the footprints were no longer visible.

After the first three samples had been tested, a fourth sediment sample was collected. This time it was clay that showed organic growth in the form of a green photosynthetic layer on the surface. The clay was collected outside of Derby Hall on The Ohio State University campus.

Like the other sediments, the clay was allowed to sit for about a month under the same conditions as the first three samples. This clay was hydrated with organic-rich water. The chicken feet were once again used to make prints in the sediment. The sediment was allowed to dry out and then was rehydrated once every twenty-four hours. This was repeated for five days. The clay was then left to desiccate completely over the course of a week.

Results

None of the first three sediment types (organic-poor sand, organic-rich sand, organic-poor clay) showed distinct evidence of green, photosynthetic microbial growth. However, the organic-rich sand smelled of organic decay when wet.

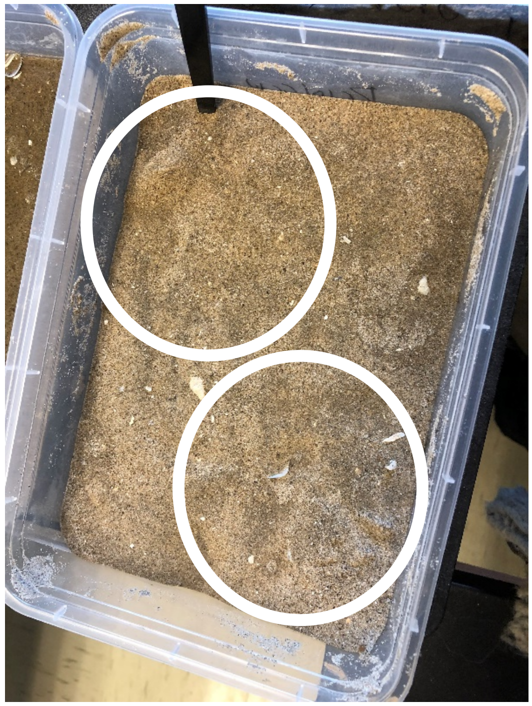


Fig. 6: Organic-poor sand with footprints.

Fig. 7: Organic-poor sand after water was applied.

The initial imprints of the chicken feet in the organic-poor sand were faint (Fig. 6), as the sand was firm and did not give way to the force of the chicken feet. The organic-poor sand did not retain any impression of the footprints after the first application of the low-organic lake water (Fig. 7).

Fig. 8: Organic-rich sand with footprints.

Fig. 9: Organic-rich sand after the first application of water.

Fig. 10: Organic-rich sand after the second application of water.

The organic-rich sand held footprint impressions better than organic-poor sand (Figs. 8, 9). After two cycles of applying the water and allowing the sediment to dry out, the footprints were no longer visible (Fig. 10).

Fig. 11: Organic-poor clay with footprints.

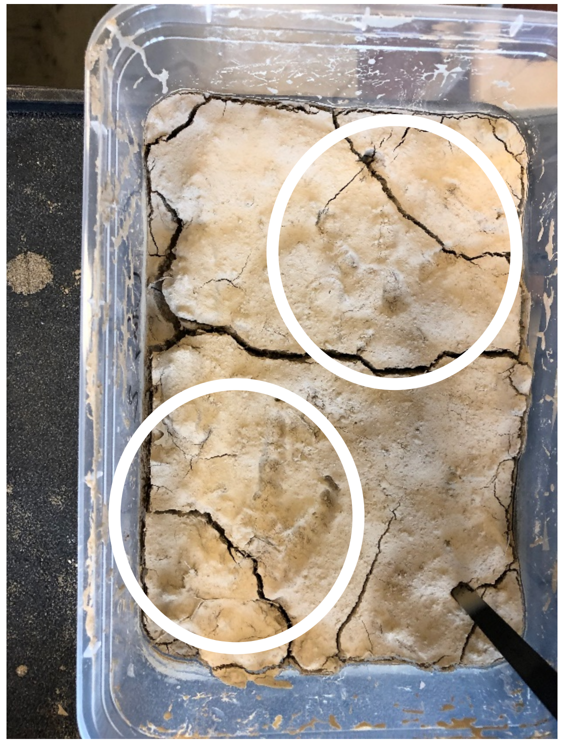
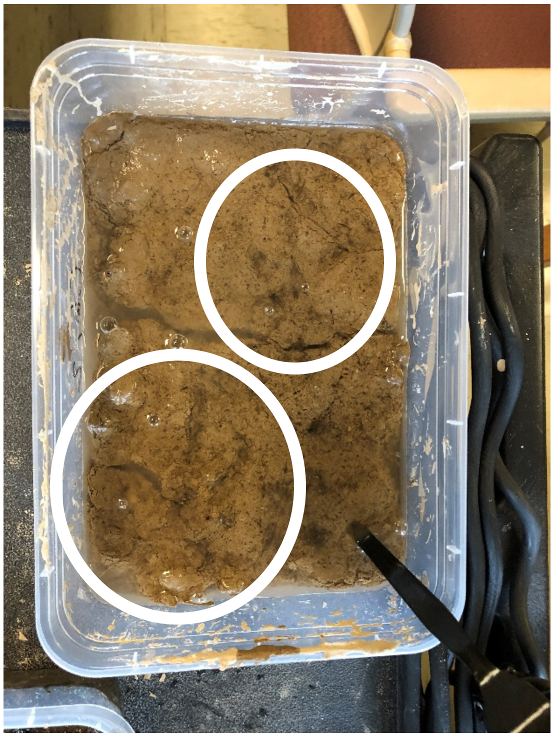


Fig. 12: Desiccated organic-poor clay after the first application of water.



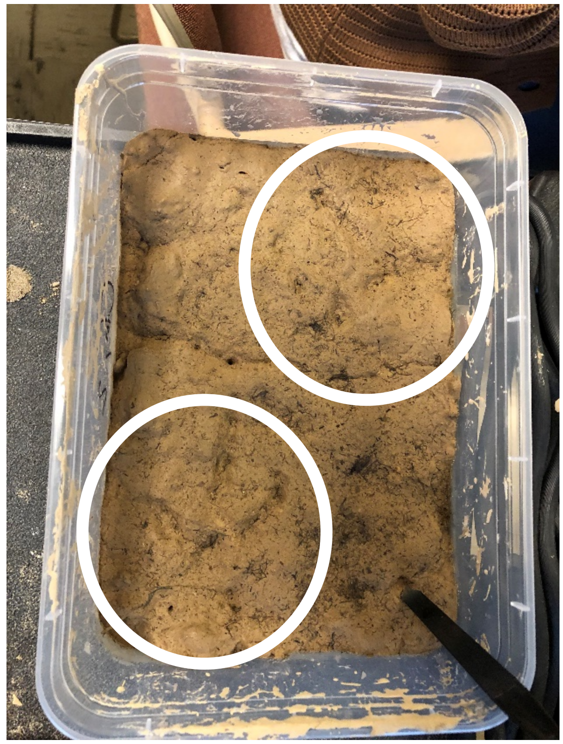


Fig. 13: Clay after the second application of water. Fig. 14: Clay after the third application of water.

The low-organic clay retained impression of footprints even after three wet-dry cycles (Figs. 11-14). During the periods of desiccation, the clay also formed mudcracks (Fig. 12). After the third cycle, the footprints were still visible, but they were faint, and difficult to distinguish from natural variations in the surface of the clay when completely dry (Fig. 14).

Fig. 15: Organic-rich clay after footprints were applied. Fig. 16: Clay after two days of the wet-dry cycle.

Fig. 17: Clay after five days of the wet-dry cycles, followed by another week of drying.

The organic clay showed a small amount of plant growth, evidently a moss. After the footprints were made, they remained visible after five days of wet-dry cycles and a further week of drying out (Figs. 13–17). This clay formed mudcracks after drying (Fig. 17).

Discussion

The sediment types chosen were intended to simulate the different types of sediment that would be found in areas around bodies of fresh water. Specifically, they were intended to serve as an analog for sediments present in paleoenvironments of the Connecticut River Valley during the Early Jurassic.

When performing the experiment, the organic-poor sand was not expected to perform well in preserving the footprints. The unconsolidated and coarse-grained nature of the sediment made it unlikely that footprints in this sediment would last long enough to eventually be buried and preserved. Results of experimentation were as expected: footprints did not preserve well, and with wet-dry cycles, disappeared completely.

The organic-rich sand, which was similar in grain size to the organic-poor sand, retained footprints somewhat longer than the organic-poor sand, even after drying out and being rehydrated once. However, after repeated wet-dry cycles, they disappeared. If the organic-rich sand had been buried by more sediment rapidly after the formation of the footprint, it could preserve footprints for a longer period of time. The presence of organic matter, including microbial components, probably increased cohesion among the grains. By contrast, the organic-poor sand showed little cohesion among the grains, leading to disappearance of the footprints in short order.

The organic-poor clay held footprints through several applications of water and subsequent drying out. Eventually, however, the impressions became faint enough that it was difficult to discern them as distinct from natural variations in the surface of the clay. Identifying them would be difficult if one did not already know where they were located. Similar to footprints in the organic-rich sand, those in clay would need to be buried fairly quickly, though not necessarily so quickly, to preserve them over a lengthy period of time. The minute grain size of the clay, and perhaps other factors, resulted in much greater cohesion of sediment, so footprints were not as easily eroded by cycles of hydration and desiccation.

The footprints were retained best in organic-rich clay. Even after the fifth wet-dry cycle, the footprints were still discernable. Organic-rich clay showed a high level of cohesion, allowing the footprints to retain their shape through repeated wet-dry cycles. It is likely that microbes including cyanobacteria acted as a biofilm, stabilizing the sediment surface, and assisting in the longer-term retention of the footprints.

The composition and grain size of the sediment, together with the degree of water saturation, apparently plays a major role in footprint preservation. The results of experimentation reported here show that a footprint has its best chance of preservation if it is impressed in sediment having a high level of cohesion. The presence of an organic biofilm at the sediment surface seems to increase to the likelihood of preservation. Carvalho et al. (2013) reached a similar conclusion after examining fossil dinosaur footprints from the Sousa Basin (Cretaceous) in Brazil. In the example cited by Carvalho et al. (2013), a microbial mat at the sediment surface not only helped produce a cohesive sediment surface, but also may have led to early lithification. Microbial mats have also been found aiding the preservation of other rarely preserved fossils, such as in Borkow and Babcock (2003), where they were found along with soft tissues preserved in pyritized concretions.

The size of the print, and the size of the animal making it, would also likely play a role in the relative preservation potential of a footprint. The chicken used was comparable in size to smaller theropod dinosaurs of the Mesozoic, and would not possess the mass to leave a deep impression in most sediments. Also, shallow impressions made by relative light animals would not lend themselves well to preserving undertracks, or flexures induced in sediment layers below the sediment surface. Larger and heavier animals would be expected to leave deeper impressions and also to produce undertracks.

Conclusions

Experimentation shows that that coarse-grained, unconsolidated sediments such as sands, do not preserve traces well in ephemerally wet environments. In some cases they may not preserve at all. Finer grained and more cohesive sediments, such as clays, preserve traces well in ephemerally wet environments. The presence of organic material (microbial biofilms) in sediment improves the preservation potential of traces. Footprints degrade through repeated wet-dry cycles. Rapid burial is necessary regardless of sediment type or organic content.

Recommendations for Future Work

Future work could involve the use of other types of sediment, such as carbonate sediments, as well as expressly testing the effects of mat-stabilized sediments. The carbonates would be used to mimic environments such as those of the Green River Formation (Eocene), of Utah, Wyoming, and Colorado. Other future work might involve searching for any preserved organic matter present in fossil footprints.

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