Exploring Dinosaur Tracks At Amherst College

A tour of Professor Hitchcock's curious "footmarks on stone"

The collection of dinosaur tracks and other trace fossils at Amherst College is one of the largest and most diverse in the world. The college's collection began in 1835, though fossil footprints were known to local people for many years before they were scientifically studied. These tracks were collected — all from the Connecticut Valley in Western Massachusetts — and closely studied by Professor Edward Hitchcock, Amherst College's first geologist as well as its third president, and the first state geologist of Massachusetts. Many of these footprints were found before the word "dinosaur" even existed. Working with the limited understanding of paleontology and geologic time available in the early 19th century, Hitchcock reasoned that these bizarre fossil footprints were made by large birds that lived long before humankind — perhaps hundreds of thousands of years ago. While he was not entirely correct, especially in greatly underestimating the age of these fossils, Hitchcock's ideas were rather ahead of their time. These studies were the foundations of ichnology, the study of fossilized tracks and traces.

Despite the extreme scarcity of skeletal remains from land animals such as dinosaurs in the Connecticut Valley, studies of the area's geology and of the many tracks found here can give us a good understanding of the ancient environment and its inhabitants. These tracks date back about 190 million years, to the early part of a geologic period called the Jurassic. At that time, the North American continent was separating from Africa, and the area that would become the Connecticut Valley was a rift valley occupied by a large lake. The small mountains of Western Massachusetts today would have been recently-formed and much taller then, perhaps comparable to the modern Himalayas. The climate was very dry and very warm, so the presence of a lake in this lowland basin would have allowed plants to thrive and attracted animals looking for food and water. The diorama near the right entrance to the track room provides more information about the local environment, as does the central display on the museum's upper level.

This guide will provide information on some especially interesting fossils in Hitchcock's ichnological collection. To begin, enter the track room through the right entrance, past the diorama and the doors to the hallway.

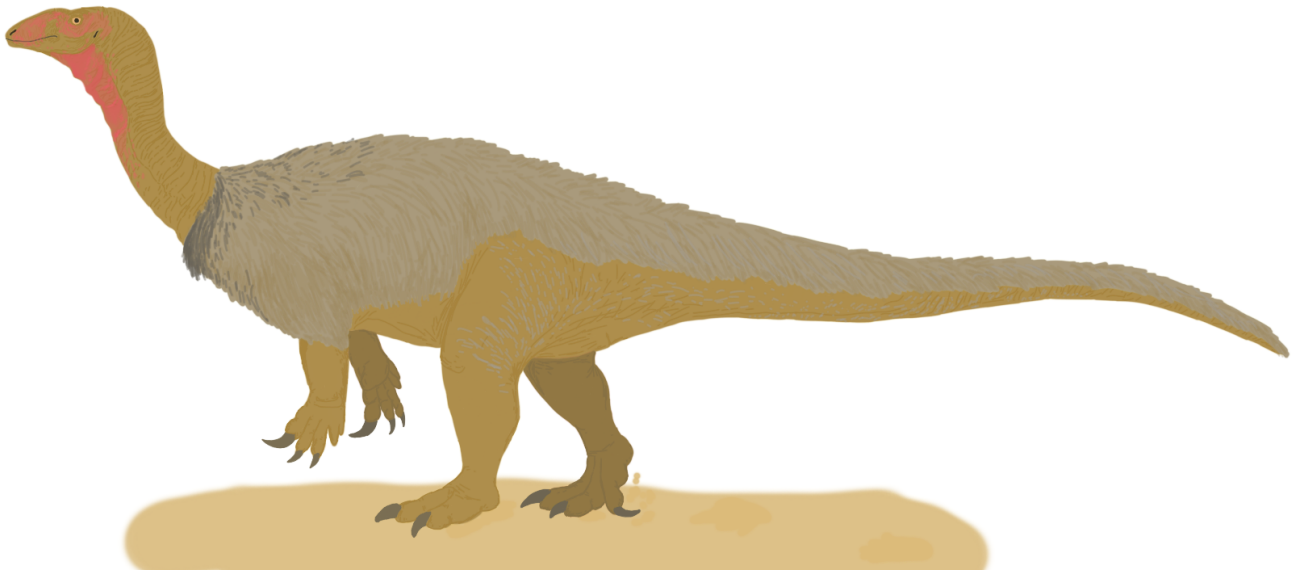
Station 1. *Otozoum*

Specimen Number: 4/1

Collected: South Hadley, 1847

The broad, four-toed tracks called *Otozoum* are made by primitive sauropodomorphs ("prosauropods"), bipedal plant-eating or omnivorous dinosaurs related to later giant sauropods like *Apatosaurus*, *Brontosaurus*, and *Diplodocus* (the legs of which are in the dinosaur hall). A model of an *Otozoum* trackmaker features in the diorama just outside the track room; the individual that made these tracks would have looked similar, though it was considerably larger — the makers of large *Otozoum* tracks were probably the biggest animals in this environment. Notice the cushioning pads on the toes; just like on the feet of modern birds, extinct dinosaurs' toe pads each corresponded with a toe bone. Examining the arrangement of toe pads can help paleontologists determine what sort of animal made particular tracks.

This *Otozoum* trackway (series of footprints) was collected at the Moody homestead in South Hadley, and though it's presented as a single continuous trackway, it is actually made of a couple of separate slabs from the same site. They were probably all made by the same "prosauropod" individual, but the slabs were not unearthed in this exact arrangement. Take a close look at these rocks and you may notice a number of interesting details. The slabs contain small, three-toed "brontozoid" footprints that were made by small meat-eating dinosaurs, as well



as tiny circular impressions made by raindrops. Paying close attention to the *Otozoum* foot pads will reveal impressions of the small, pebbly scales that covered its feet in life; though it had scaly feet, recent evidence suggests that this animal's body may have sported simple, fuzzy feathers.

Station 2. Interference Ripples

Specimen Number: 13/10

Collected: South Hadley, year unknown

What made the strange honeycomb- or bubble wrap-like patterns on these mudstone slabs is one of the most frequently-asked questions in the museum. These patterns are sometimes guessed to be skin impressions from dinosaurs lying down in the mud. However, remember the fine, bumpy scales on the *Otozoum* foot pads in Station 1; these patterns are too big, too smooth, and too regular, and they don't show signs of an animal moving to lie down or get up. These "tracks" actually don't contain evidence of animals at all; instead, they are fossilized ripples. These marks are produced when shallow water ripples in a criss-crossing pattern over a muddy bottom. Exposure to the sun may help preserve these water-generated features in the mud. Despite the absence of animal prints, these slabs with ripples are key to understanding the environment that enabled the preservation of the footprints. Without soft muds and fine sands in a gentle depositional environment like a lake or a sluggish river, and without (at least occasional) exposure to the air, the tracks that fill this room would not be present in such diversity or quality. They would have either been swept away by currents or eroded away by wind and exposure, if they had even been made at all.

Station 3. Gimpy

Specimen Number: 64/2

Collected: unknown

These tracks were made by a small theropod. Theropods are bipedal, usually meat-eating dinosaurs; modern birds are living theropod dinosaurs. Three footprints are present on this slab: right foot, left foot, right foot again. Take a look at the print from the left foot, in the middle. It has the classic theropod form: three pointy, forward-facing toes. These are the most common

footprints in the Valley, and are referred to as brontozoids, with the name *Grallator* generally being used for small ones and *Eubrontes* for large ones. Now compare the right footprints to the classically-brontozoid left foot prints. They are narrower and much deeper, and the sediment is squished up at their edges. Why? Count the number of toes on these footprints — only two! The animal is spreading its weight over a smaller area, so the prints are deeper, and the way they are impressed suggests the trackmaker was walking with a limp. This poor little theropod had lost its inner toe on its right foot, likely in a fight or to a predator. Pathology is the term for an injury or disease observed in the fossil record and fossils that show such injuries or diseases, like these tracks, are described as being pathological.

Station 4. Origins, Part 1

Specimen Number: 18/1 and 18/2

Collected: Montague (excavated)/Greenfield (collected), 1835

These paired slabs were the first in Amherst College's (or any college's) collection of fossil tracks. These mudstone slabs fit together — one contains the tracks of a dinosaur, the other contains the raised natural casts of those tracks, created when the next layer of mud buried the footprints and filled in their shape. You may notice that these slabs are almost perfectly square. They were cut to be sidewalk flagstones in the town of Greenfield. In 1835, a doctor named James Deane observed the strange marks on these slabs before they were installed and purchased them. Curious, Deane eventually made contact with the geology professor at Amherst College, Edward Hitchcock. Hitchcock examined these ancient tracks and found them fascinating, buying them from Deane for the college. He would study the fossil tracks in the Connecticut Valley until his death in 1864, in the process amassing the amazing collection housed here today — one of the largest anywhere in the world.

Station 5. Origins, Part 2

Specimen Number: 16/2

Collected: South Hadley, ~1802

While the paired Greenfield sidewalk slabs were the first dinosaur footprints to be collected by Hitchcock, they were not the first ones discovered in the area. Dinosaur tracks had been known in the area for around 30 years, beginning when this track, popularly known as "Noah's Raven," was unearthed. It was found by Pliny Moody, then a teenager, when he was working on the family farm in South Hadley. Discovered in 1802 — 40 years before British anatomist Richard Owen would coin the word "dinosaur" — it is the first dinosaur track ever collected and probably the first dinosaur fossil found in North America. These tracks are called *Anomoepus*, and they belong to a beaked, bipedal plant-eater called an ornithischian.

As the name Noah's Raven suggests, these dinosaur footprints were initially thought, quite reasonably, to have been made by ancient birds. At the time the tracks in the Valley were discovered, dinosaurs were known only from (usually quite scrappy) fossils in England and later elsewhere in western Europe, and they were not yet recognized as a unique group; all that was known from the bones was that they represented very large extinct reptiles that had upright limb posture, unlike the sprawling limb posture of other reptiles. The footprints from the Connecticut Valley did not match this interpretation very well, showing active, birdlike animals that were often of small size, rather than gigantic, sluggish reptiles, but were very similar to the tracks produced by modern-day ground birds like turkeys. In light of this, Hitchcock and others interpreted these fossils as the tracks of extinct birds. Though today we know these tracks were made by non-bird dinosaurs, in many ways Hitchcock's early ideas have been supported by a vast amount evidence gathered since the 1960s; today we know that dinosaurs were warm-blooded, active, successful, and very birdlike in many aspects of their behavior and life appearance, including feathery body coverings in many dinosaur groups. The living birds are, in fact, a surviving group of dinosaurs.

Station 6. Objects In Motion

Specimen Number: 27/21

Collected: Turners Falls, year unknown

These strange marks were probably produced when flowing water pulled sticks along with it, scraping them against the intermittently exposed-and-submerged sediment at the lake's bottom. The sediment often developed a thin film of microorganisms on its surface, which made it more cohesive. When the sticks were dragged across the sediment's surface, they scraped these grooves into it, and the cohesive mud rippled up in the ruffly patterns you can see here, branching off from the central groove. Additional evidence of a current can be seen in the multiple series of small, rounded impressions running parallel to the stick drag marks. These are the traces of small pebbles or other objects being carried by the flow, bouncing along the bottom in a form of motion called saltation. Features like these that are produced when water carries objects that leave marks in the sediment are referred to as sole marks. The presence of a thin microbial film on the sediment's surface has important implications for the preservation of footprints in the Connecticut Valley; this thin coating of microorganisms gave the mud a little extra cohesion and firmness that could help footprints more readily hold their shape after being made, and thus be more likely survive burial and lithification (turning to stone).

Station 7. Beach Bum

Specimen Number: 1/7

Collected: Barton Cove, prior to 1858

Take a close look at this track, found at a site called Lily Pond Quarry. It was produced by a single theropod dinosaur on the shore of the lake. What might it have been doing to make this odd track? Notice the three-toed footprints at the top of the slab (the left footprint is not as clear as the right one), and the long, narrow impressions projecting backward from them. Near the bottom of the slab, there is a smaller, circular impression.

This mark was produced by a dinosaur sitting down. Its whole feet are flat on the ground, accounting for the long, narrow marks behind the three pointed toes. Dinosaurs, like most animals, are digitigrade, meaning they walk on their toes with their heels held off the ground. Standing up on your tiptoes might help you visualize this. This impression was created by the animal folding its legs up under its body like a sitting bird, and placing the entire foot down. The

small, circular imprint near the bottom of the slab is made by the dinosaur's ischia (hip bones). In dinosaurs, these hip bones jut backward and downward behind the hindlimbs at the base of the tail. Look out the window at *Dryosaurus,* the small bipedal skeleton in the dinosaur hall. You'll notice the ischia point back and down underneath the tail. In life, these jutting bones would've formed a small bump. When this dinosaur sat down and produced this track, this bump was resting on the sediment along with its feet. Unfortunately, this slab is broken off before we could find any evidence of hands resting on the ground, but other similar sit-down fossils from the Connecticut Valley and the Southwest US have preserved some hand impressions.

Station 8. Raindrops Keep Fallin' On My Sediment

Specimen Number: 28/6

Collected: Turners Falls, 1863

This interesting slab is covered in small, circular impressions. These features were not made by an animal, but rather by weather. They probably represent a heavy rain at the shore of the lake. This rainfall could not have lasted long, though, because continued rain would have washed away the delicate impressions of the raindrops hitting the soft sediment. For this reason, some scientists propose that the marks could potentially be made by hailstones rather than large raindrops. There are animal tracks preserved in this slab, though; look closely at the left side of

the slab and you may notice small, squiggly trails produced by invertebrates crawling across the sediment.

Station 9. Showing Off

Specimen Number: 23/2

Collected: Turners Falls, prior to 1858

This slab preserves *Anomoepus* footprints, the same as the Noah's Raven tracks. Additionally, there are small brontozoid tracks, which again show evidence of a missing toe (remember Station 3). However, there are more marks than just footprints here. Near the clear *Anomoepus* track on the lower part of the slab, there are narrow, deep impressions. Hitchcock initially interpreted these as the footprints of some sort of lizard with outward-angled feet with two toes each. Modern interpretation disagrees with Hitchcock's assessment, but provides an equally interesting explanation. Note that these marks are paired. One of the marks on the left is shorter than the other, and one of the marks on the right is shorter than the other, and these shorter marks are mirrored from one another. It is believed these could be scrape marks made by a small ornithischian dinosaur flapping its arms and swiping the back of its hands across the sediment. This curious potential display is similar to some showy behaviors performed by some modern birds, like grouse.

Station 10. Reptiles of a Feather

Specimen Number: 48/1

Collected: Turners Falls, prior to 1858

This long slab, again preserving *Anomoepus* tracks, is one of the most interesting in the museum. The blunt, three-toed footprints of this small plant-eating dinosaur show it moving from the right end of the slab to the left end. At the far right, you may be able to find a very narrow, slash-like impression in the sediment; this is the end of the dinosaur's tail resting on the ground. There are also small, five-fingered hand prints in this area, showing that the dinosaur was either crouching or sitting. These impressions are very faint; you will have to look carefully to spot them. After making these marks, the dinosaur got up and continued walking toward the left. Look at the footprints near the middle and you'll clearly be able to see the toe pads associated with the toe bones as well as the fine, bumpy texture of the small scales on the bottom of the feet. Note also the impressions from the keratinous (horny) coatings on the claws.

At the very far left of the slab is a remarkable impression. You may need to remove the doorstop and close the door to get near enough to see it. Take a close look at the very edge of the slab and you can observe a patch of pebbly texture that grades into regular, rectangular impressions, which narrow out into a slender slash in the sediment. This is another tail impression, like the one you saw on the right of this slab, but showing more of the tail in better quality. The clarity shows that the *Anomoepus* trackmaker didn't drag its tail, but merely rested it on the ground. The pebbly-textured patch is from scales at the base of the tail, and the rectangular impressions

are scutes (plate-like scales) running along the bottom of the tail towards the tip, somewhat like an alligator's underside. Looking even more closely at the tip of this tail impression, you can spot several structures branching off it, and leaving very faint, brushy marks in the sediment. These are the impressions of simple feathers, which would have covered the dinosaur's body and the top side of its tail.

In 2014, excellently-preserved fossils of a small ornithischian were found in Russia. Named *Kulindadromeus*, this little dinosaur was fossilized with scales and simple feathers as well as bones. While its head, body, and thighs were covered with feathers, the hands, lower legs, and tail bore scales, just like this impression shows. The scales along the tail were rectangular platelike scutes arranged in rows, just as in this track. Despite the striking similarities, there are a few notable differences. It is unknown whether the tail of *Kulindadromeus* was totally scaly, or if it possessed feathers along the top like the *Anomoepus* trackmaker. Additionally, fossils of *Kulindadromeus* are estimated to be about 160 million years old, from the Late Jurassic. This *Anomoepus* trackmaker lived at the beginning of the Jurassic Period, more than 190 million years ago. Although these feather impressions are among the oldest-yet evidence of feathered dinosaurs, interpretations drawn from the relationships of dinosaur groups to each other and to other reptiles strongly suggests that dinosaurs already possessed simple feathers at the time of their evolutionary origin, roughly 235 million years ago.