Title: Fossil focus: Vertebrate Tracks and Trackways
Author(s): Peter Falkingham[*1]
Volume: 2
Article: 1
Page(s): 1-6
Published Date: 01/01/2012
PermaLink: http://www.palaeontologyonline.com/articles/2012/fossil-focus-vertebrate-tracks-and-trackways/

Fossil Focus: Vertebrate Tracks and Trackways

by Peter Falkingham *1

Introduction:

The fossilized footprints and trackways of vertebrates are often overlooked in favour of the skeletal remains of the animals that made them. At museums, for instance, many more people will crowd around the dinosaur skeletons than around the dinosaur tracks nearby, and yet fossilized tracks can provide us with information about extinct animals that is simply not available from the bones alone. A track is the result of an interaction between an animal and a surface, or substrate. The final track shape (morphology) is directly determined by three factors:

- Producer: the shape of the track-maker's foot
- Behaviour: the motion and loading (kinematics and kinetics) of that foot
- Substrate: the conditions of the surface when the track is made (sandy, muddy, wet, dry etc)

By studying tracks, we can hope to tease apart the relative contributions of these factors in any given track, and ultimately to 'reverse engineer' the formation of a track to understand both the palaeobiology of the animal that made it, and the environment in which it was made.

FIGURE 1 - SAUROPOD TRACKS IN PORTUGAL LARGE ENOUGH FOR AN ADULT TO SIT IN.

Studying Tracks:

Research into fossilized tracks left by vertebrates typically falls into one of two categories: ichnotaxonomy and experimental work/neoichnology.

Ichnotaxonomy

Ichnotaxonomy deals with the description and classification of tracks, in much the same way that taxonomy deals with tehe description and classification of organisms. Indeed, like taxonomy, ichnotaxonomy uses the binomial Linnean naming system, including ichnofamilies, ichnogenera, and ichnospecies. It is common in the scientific literature to see tracks with names such as ***Brontopodus birdi*** or ***Tyrannosauropos*** (many of these ichnotaxa end in ***pus***, the Greek word for foot, or ***ichnus*** meaning trace). By describing and naming tracks, ichnologists are able to refer easily and quickly to specific types of trace. However, the reader should be warned that even if a track name sounds like the name of a producer (for example, ***Tyrannosauropus*** sounds like ***Tyrannosaurus***), the former was not necessarily produced by the latter. In fact, determining the producer of a fossil track to any degree of specificity is notoriously difficult – if it is possible at all.

Experimental work/neoichnology

The other side of track research is experimental work. Vertebrate tracks are amazingly complex three-dimensional structures, both at the surface and extending into the substrate beneath (see undertracks, below). This three-dimensional morphology is the direct result of the combined effects of producer, behaviour and substrate. By studying track formation in the lab or in the field, we can hope to associate features of tracks with specific foot motions or substrate conditions (such as moisture content). The earliest record of experimental ichnology is from the 1830s, when William Buckland encouraged tortoises to walk over warm pie crust to give him a basis from which to interpret tracks found in sandstone.

Experimental work examining ‘undertracks‘ or ‘transmitted tracks’ has been of particular interest in recent years. They were first recognized in 1858 by US geologist Edward Hitchcock (1793–1864). Undertracks form when the force from an animal stepping on a substrate is transmitted to subsurface layers. The result is a sequence of ‘tracks’ in each sediment layer, each of which represents in some way the original track. Undertracks are of great interest to track workers, because the direction of deformation and the depth to which the undertracks extend can tell us much about the forces involved in limb motion and the conditions of the substrate when the track was formed.

Locomotion

One of the most common interpretations of fossil trackways relates to the speed at which the animal was travelling. When Buckland was conducting his trackway experiments with tortoises and crocodiles, he noted in a letter to Scottish geologist and minister Henry Duncan (1774–1846) — who had published the first ever account of a fossilized track in 1831— that he “found considerable variety in these positions [of footprints] as tortoises moved more or less rapidly and [that] most animals have three distinct kinds of impressions for their three paces of walk, trot, and gallop”. From this, Buckland determined that the fossil tracks that he was studying had been made by animals that moved faster than the ones that he had used in his experiments.

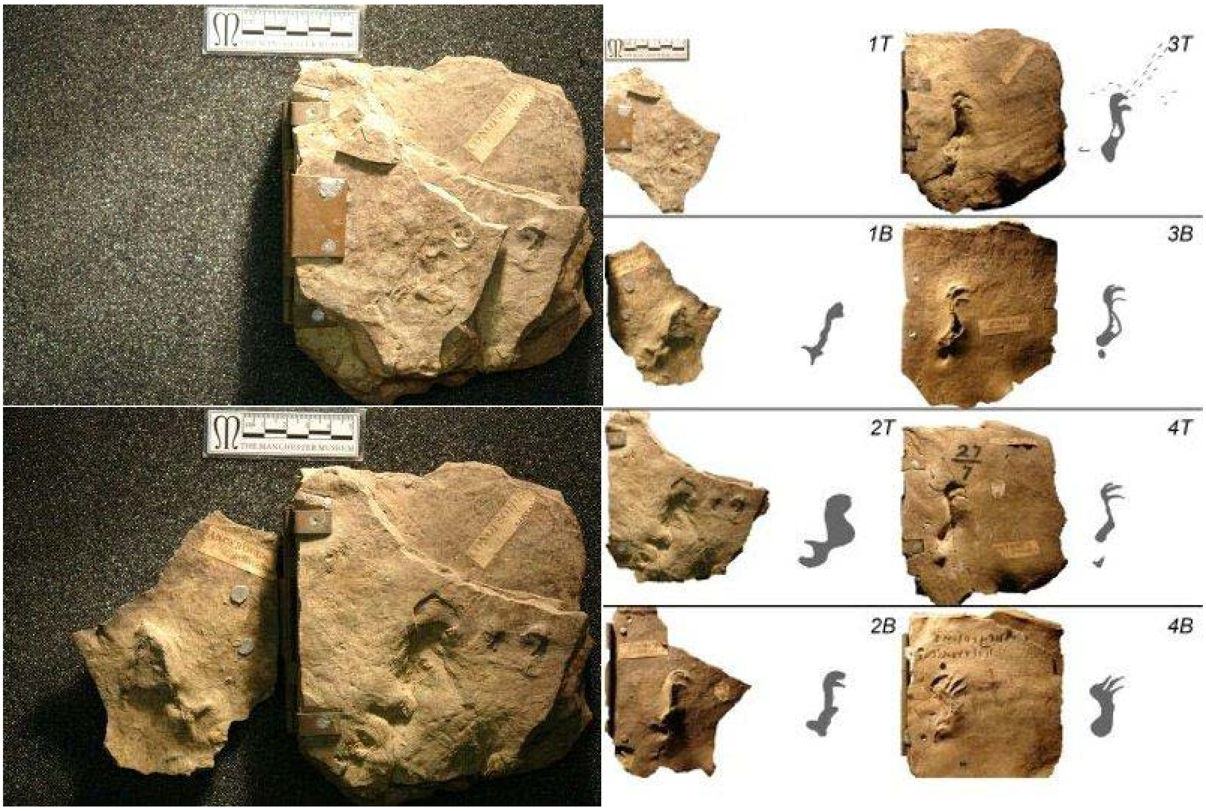

FIGURE 2 – ONE OF EDWARD HITCHCOCK'S 'TRACK BOOKS' DISPLAYING A FULL UNDERTRACK SEQUENCE. 'T' AND 'B' REFER TO TOP OR BOTTOM OF EACH 'PAGE.' BOTTOM SURFACES HAVE BEEN MIRRORED FOR COMPARING WITH TOP SURFACES.

In 1976, British zoologist McNeill Alexander quantified the relationship between trackways and speeds with the following formula:

$$\boldsymbol{u} = 0.25 \times \boldsymbol{g}^{0.5}\boldsymbol{\lambda}^{1.67}\boldsymbol{h}^{-1.17}$$

Where $\boldsymbol{u}$ is speed, $\boldsymbol{g}$ is the acceleration due to gravity, $\boldsymbol{\lambda}$ is stride length and $\boldsymbol{h}$ is hip height (calculated as 4 times foot length). This equation has frequently been used to estimate the speeds at which dinosaurs could move. You can find a handy online calculator produced by a group at the University of Sheffield.

Tracks can also be used to examine the motion of the foot, by observing the depths of different parts of a track, and how that correlates with the track-maker's foot. For example, a human footprint will often be deepest at the heel and under the pads of the toes. In humans, this results in part from the shape of the feet (which include an arch), but also from pressure — as a person places their foot on the ground, they land heel first, with only a small surface area supporting the body. As the foot rolls forwards, the surface area increases and then decreases again. This results in high–low–high pressure as the foot makes a track, with the deepest parts of the track corresponding to the areas of highest pressure. We can apply the same principal to fossilized tracks to learn how the foot of the producer moved when it touched the ground. In this way, tracks can help us to understand how animals such as dinosaurs moved.

Behaviour

Tracks represent one of the best sources of evidence regarding the behaviour of extinct animals. Paluxy River in Texas, USA, records one of the most famous instances of behaviour captured in tracks, where the tracks of a large, herbivorous sauropod are closely followed by the tracks of a large, carnivorous theropod. It is difficult to say whether the theropod was actively hunting the sauropod, or merely following a short time after it had passed through, because the surface may have been exposed for some time before being buried and fossilized. Nevertheless, the tracks show that the animals lived in the same environment, and very probably interacted with each other.

Other evidence may come from parallel trackways that potentially preserve evidence of group or herd behaviour, or enigmatic tracks appearing as scratch marks, which have been interpreted as dinosaur swimming traces, in which the claws of the feet have scraped at the top of the submerged sediment.

FIGURE 3 - THESE SINUOUS MARKS HAVE BEEN INTERPRETED AS DINOSAUR SWIM TRACES, FORMED AS THE DINOSAUR'S CLAWS SCRAPPED THE BOTTOM OF AN ANCIENT RIVER.

Palaeoenvironment

It can be difficult to work out what environment an animal lived in on the basis of the sediments in which body fossils are found, because after death an animal might have been transported by a river or scavenger for some distance from the area in which it actually lived. Tracks suffer from no such problem — a track cannot be preserved in any sediment other than that present where the animal was active. Fossil tracks therefore make excellent palaeoenvironmental indicators. The environments necessary for preserving body fossils are also quite different from those necessary for preserving tracks: whereas body fossils require rapid burial to escape scavenging or decay, tracks must dry out or be buried slowly to avoid disturbance of the soft substrate. This means that tracks and body fossils are often found in different types of rock, so tracks can provide evidence of animals that are otherwise not represented in a given set of rock layers.

When used in conjunction with other sedimentary features such as ripple marks, long, parallel trackways can be used to infer the locations of palaeo-coastlines (as animals walk around the body of water), whereas tracks containing peculiar sediment slumps can be used to determine the original slope of a substrate such as sand dunes.

FIGURE 4 - LARK QUARRY, IN CENTRAL QUEENSLAND, AUSTRALIA, PRESERVES HUNDREDS OF DINOSAUR TRACKS. ALMOST ALL OF THESE WERE MADE BY SMALL, PROBABLY HERBIVOROUS DINOSAURS, EXCEPT FOR ONE TRACKWAY MADE BY A LARGE CARNIVOROUS DINOSAUR. THE SITE HAS BEEN INTERPRETED AS THE ONLY FOSSILIZED RECORD OF A DINOSAUR STAMPEDE.

Fossilized tracks can provide a wealth of knowledge about extinct animals and the habitats in which they lived — knowledge that is complimentary to that obtained from body fossils. As such, tracks are an integral part of many aspects of palaeontology, and greatly enhance our understanding of the history of life on Earth.

Suggestions for further reading:

Falkingham, P. L., Bates, K. T., Margetts, L. & Manning, P. L. 2011. The 'Goldilocks' effect: preservation bias in vertebrate track assemblages. ***J. R. Soc. Interface*** **8**, 1142–1154. (doi:10.1098/rsif.2010.0634)

Sellers, W. I., Manning, P. L., Lyson, T., Stevens, K. & Margetts, L. 2009. Virtual palaeontology: gait reconstruction of extinct vertebrates using high performance computing. ***Palaeontol. Electron.*** **12**, 11A. http://palaeo-electronica.org/2009_3/180/index.html

Thulborn, R. A. 1990. ***Dinosaur Tracks***. London: Chapman & Hall. ISBN 9780412328909

Thulborn, R. A. & Wade, M. 1984. Dinosaur trackways in the Winton Formation (mid-Cretaceous) of Queensland. ***Mem. Queensl. Mus***. **21**, 413–517.

---

[1] School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Oxford Road, Manchester, United Kingdom.