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DIRTY FEET LEAVE DIRTY TRAILS: NOTES ON THE RELATIONSHIP BETWEEN COPROLITES AND TRACKS

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Abstract—Tracks and feces, as well as tracks in feces, are ubiquitous in modern environments, but tracks in coprolites are rare in the fossil record. A small case study shows that Canada Geese transfer feces to hard substrates, as dirty footprints, where they may be preserved for several weeks without being weathered or eroded away. In such cases their preservation potential may be equal to or greater than tracks made on soft substrates. However, the potential for finding such dirty footprints on hard substrates in the fossil record is virtually unknown and unexamined.

INTRODUCTION

Although almost every human pedestrian and quadruped rider knows that it is easy to step in feces, the subject of how important such activity might be for the ichnologist to understand has generally not been considered in any detail: one might even say the subject has been avoided! While it is obvious that vertebrate trampling and general track-making activity must play some role in redistributing dung, with obvious consequences for the fertilization of substrates, the study of the phenomenon is hardly a recognized field in taphonomy. Here one might also note that the deliberate redistribution of dung by farmers is an activity of at least secondary interest to soil scientists and even to ichnologists.

Dung beetles, as their name implies, play an important role in redistributing feces in the modern environment (Hanski and Cambefort 1997), and are known to have been active back into the Mesozoic (Chin and Gill, 1996). Their recognizable burrows in modern and ancient feces indicate unequivocal and relatively common associations between invertebrate trails and vertebrate feces, which in turn add useful information on the redistribution of coprolites, and the significance for trophic systems and ecology. However, such invertebrate-vertebrate associations are different from the associations between vertebrate tracks- and vertebrate feces, not least because of different preservation potentials. In comparison with the relative abundance of infaunal dung beetle traces in ancient environments, reports of vertebrate footprints in coprolites are rare (Anton et al., 2006). This is perhaps because the tracks in coprolites are an "epifaunal' phenomenon, rather than infaunal traces, as is the case with burrowing invertebrates.

Observations of modern Canada Geese, creating copious fecal material which they distribute and redistribute in ways that humans find objectionable, has led to the following brief observations and ruminations. In this short report, I discuss trackways made by Canada Geese (*Branta canadensis canadensis* Linnaeus) on cement surfaces after they had stepped in dark, viscous excreta made by other members of their flock. These cases are interesting because the chemistry of excrement is such that it serves as a powerful pigment and staining agent which survived a significant period (20+ days) of winter weathering, and therefore indicates the potential to survive in the fossil record.

DESCRIPTION OF MATERIAL

On Feb. 6th 2009, the author noticed a series of black footprints (Fig. 1) made a by a Canada Goose on the cement sidewalk outside a Recreation Center in the City of Golden, Jefferson County, Colorado. It is not known exactly when the footprints were registered, but they were likely made that day or in the previous 24-48 hours. In certain winter months, including both January and February, Canada Geese are seen almost daily at the site, and so it is inferred that no other birds of comparable size frequent the area as a possible track maker. The tracks are also the right size (~5.8 cm long and 7.8 cm wide) to fit a Canada

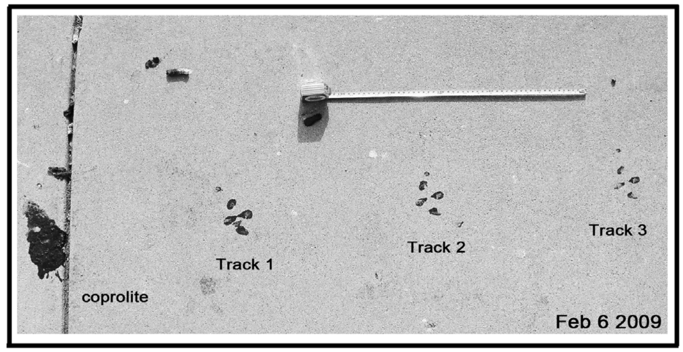

FIGURE 1. Dirty footprints made by Canada Geese in Golden, Colorado, Feb. 2009.

Goose. The origin of the tracks was clearly the result of a bird stepping in the black, tar-like "deposits" or pools of excrement on the sidewalk while they were still fluid. The relatively high frequency of making of such "dirty tracks" can be inferred from the fact that the author observed more dirty tracks elsewhere in the vicinity. Moreover, such trackmaking occurs repeatedly. Similar tracks made by Canada Geese were observed again on Jan. 24th 2010 and again on Jan. 28th 2011, both times at the same locality. Canada Geese are abundant and active in many areas along the Colorado front range, and in many other areas too numerous to mention.

In the case of the 2009 trackway, 12 dirty tracks were made beyond the excrement in which the goose had stepped with its right foot. The trackway (Figs. 1, 2) was made by a single individual (Fig. 1), no later than Feb 6th 2009. No left footprints were identified. Thus, a sequence of successive right feet preserved the stride pattern only – not the step pattern. The mean stride is 39.8 cm for the 2009 trackway (Table 1). Although Canada Goose feet are webbed, none of the footprints showed webbing traces in the 2009, 2010 or 2011 trackways. However, in the 2009 trackway, a trail of right footprints, with clear digit traces, could be followed up a slight incline for 12 steps, becoming progressively fainter until all traces disappeared. These tracks show a consistent inward rotation of about 13° relative to the trackway midline, which is typical of geese. The first three tracks were very clear and deeply colored when first observed (Fig. 1), and they were still equally clearly visible when the author returned on Feb. 7th to take photographs. The tracks remained quite clearly visible when photographed for a second time on Feb. 17th and again on Feb. 27th when photographed for a third time.

In the case of the 2010 trackway, eight dirty tracks were made, beyond the excreta, by the left foot of a single individual (Fig. 2), no later than Jan. 24th 2010. No right footprints were identified. The mean step length was 41.5 cm (Table 2).

FIGURE 2. Tracings of dirty footprints in trackways made by Canada Geese in Golden Colorado in 2009, 2010 and 2011. All tracks were made in the same location on three separate years in January or February. In all cases the tracks were registered on a cement sidewalk after the geese had stepped in a future coprolite. See text for details.

In the case of the 2011 trackway, four dirty tracks were made by the left foot of a single individual (Fig. 2, Table 3), no later than Jan. 28th 2011. No right footprints were identified. The mean step length was 41.5 cm. In all three trackways the stride lengths are relatively consistent (mean between 39.8 and 41.5 cm) indicating a normal walking gait for a Canada Goose. The steps could not be measured, for the reasons explained above, but based on observations of Canada Goose trackways in soft substrates like mud or snow, where the trackways are relatively linear and narrow (Fig. 3), one can infer that step length is approximately half stride length: i.e., in the range of 20-21 cm

ANALYSIS

Simple inspection of the footprints recorded in 2009 through 2011 indicate that the trackmakers had stepped in the viscous, black pools of excrement deposited on the sidewalk while still fluid. Given that a goose could hardly have stepped in its own excrement if it had evacuated behind its feet while walking, it seems clear that the excrement was produced by other geese. It is also clear that the geese had transferred the viscous excrement to their feet when stepping in the pool (designated as the starting point, or track 0) and then to the sidewalk as they took their next steps. However, the quantity of excreta adhering to the foot was only enough to leave very well-defined footprints in the proximal part of the trackway, nearest the excrement source. In the case of the 2009 trackway, three clearly-outlined digit traces are visible on the first three footprints, between footprint 0 in the excrement pool, and footprint 3. Subsequently, the sequence consists of six more footprints (4-9) where increasingly faint traces of all three toes were observed. The remaining footprints (10-12) consist of isolated traces of the more prominent foot pads.

In the case of the 2010 and 2011 trackways, excrement evidently did not adhere to all three toes, so the 2010 trackway consists mainly of the middle digit trace of a left foot, and in the case of the 2011 trackway we see clear traces of two digits of the left foot in four successive footprints.

PRESERVATION POTENTIAL

Such excretory deposits made by geese are common, and create problems for local authorities responsible for maintaining the landscapes around public facilities. Indeed there is a huge literature, of marginal interest here, on the damage Canada Geese to do crops, and the various methods used to prevent their grazing/feeding activities. These goose problems are exacerbated by the large numbers of birds that winter in the area discussed. They foul sidewalks, parking lots and other areas both with their excreta, which includes discrete cylindrical fecal masses, mainly composed of grassy residue, and the liquid portion of the excreta (including urine), which has the consistency of tar. Thus, the potential for such tracks to be registered in modern environments is very high.

While there are few reports of footprints preserved in or on resistant surfaces such as rock or dry cement, where it is impossible to make an impression, it is possible to leave footprints on such durable surfaces if the foot of the trackmaker has been dipped in some substance than can then be transferred to the substrate. In modern environments such tracks are seen where trackmakers emerge from a muddy area onto rock or artificial substrates like cement or asphalt, and even quite subtle traces on hard substrates can be detected by forensic methods (Bodziak, 1995). The principle is the same if an artificial substance like paint is used – as done in exercises where children create colorful footprints. Tire tracks that smear newly painted road markings are commonly observed, as are occasional footprints, mostly made inadvertently.

These tracks are durable, and are proven to last for several weeks in the cases reported here. Ironically, tracks made in soft substrates may have less preservation potential than dirty tracks on hard substrates if subjected to long exposure. For example, tracks made around the shores of Lake Manyara, Tanzania, did not last in recognizable form for as long as the dirty footprints observed in this study (Cohen et al., 1993). Incidentally, around African waterholes one commonly sees muddy 2-dimensional footprints made on firm grass substrates.

Until relatively recently fossil footprints and coprolites were both considered comparatively rare and unimportant (Sarjeant, 1987), whereas today they are known to be very abundant and of global significance in paleoecology and related behavioral and paleoenvironmental studies. Thus, it would be premature to assume that the lack of reports of fossil footprints on hard substrates, or convincing evidence of dung re-distribution by vertebrate trackmakers, reflect their complete absence in the fossil record. Of course it is obvious to the geologist and paleontologist that fossil tracks (and coprolites) are already associated with hard substrates by the time they are discovered in the fossil record. However, it is also known that there are some tracks preserved only as colored traces on substrate and have no 3-dimensional relief. Some of the best examples are those described by Stanford et al. (2007) from the Cretaceous of Maryland. In such cases, it has been assumed that the tracks were originally made on soft substrates, and that during lithification and subsequent exhumation, the now-firm substrates had been planed off to reveal tracks without any relief. Nevertheless, to someone encountering such tracks for the first time, it is easy to dismiss them as pseudo-fossils precisely because they lack relief.

TABLE 1. Stride lengths between successive right footprints in 2009 trackway.

0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
~40.5	38.0	40.5	38.0	42.0	40.5	39.5	40.5	39.5	39.5	39.0	(?36)

TABLE 2. Stride lengths between successive left footprints in 2010 trackway.

0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
~43.0	44.7	43.5	40.0	41.5	39.0	40.0	39.0

TABLE 3. Stride lengths between successive left footprints in 2010 trackway.

0-1	1-2	2-3	3-4
~40.0	42.5	41.0	42.5

FIGURE 3. Canada Goose trackways in snow, University of Colorado Denver campus, January 12, 2012. Tracks are ~ 8 cm wide and steps are ~20-21 cm. Compare with Figs. 1-2.

The potential for livestock and wild animals to transfer biological agents on their feet is well known and has generated a huge agricultural and epidemiological literature, beyond the scope of this brief exposition. Hence the potential for transfer of biological matter on the feet of ancient tetrapods was presumably high also. However, the difficult question is whether such transfers can be recorded in the fossil record. Tetrapods have the potential to register tracks on firm substrates as they leave wet areas and travel onto dry ground. In such cases they may transfer mud, or other sediment and moisture, making tracks with little or no relief (as noted in the Tanzanian example cited above). The effects or impact of water, water with various chemical or biological ingredients (salts, algae, feces, etc.) or other liquids and solids, transferred by tetrapods to firm substrates is largely if not entirely unstudied, even in modern habitats (the study of microbe or disease agent transfer notwithstanding). Thus, at present there is an equal dearth of information on similar "transfer" processes or potential in the fossil record. Nevertheless, it is possible to speculate that the transfer of feces on the feet of tetrapods, either to soft or firm substrates, has the potential to line the surface of the footprint in such a way as to physically and/or chemically alter or enhance its preservation. Thus, based on present knowledge, which recognizes the ubiquity of the dirty foot phenomenon in modern ecosystems, the question arises as to the preservation potential for such tracks in deep time. At present the question remains open and in need of further investigation

CONCLUSIONS

Tracks and coprolites are ubiquitous trace fossils in modern and ancient environments. Modern trackmakers constantly transfer sediment and biological material from place to place on their feet and presumably did so in the past.

Tracks in feces are very common in modern environments but are only rarely reported in the fossil record. Tracks created by modern geese on hard substrates as the result of stepping in excrement, are common and once created will resist weathering for several weeks. In modern environments the preservation potential of coprolite enhanced tracks on hard substrates may be as great, or greater than tracks made in soft substrates.

The preservation potential of tracks made by trackmakers with dirty feed in the fossil record is largely unknown, and may prove difficult to evaluate.

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