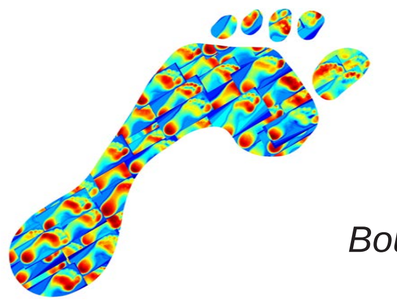
Substrate and Track Topology Namibia



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ABSTRACT

We report a Holocene human and animal footprint site from the Namib Sand Sea, south of Walvis Bay, Namibia. Using the data, we explore intra-trail footprint variability associated with variations in substrate properties using a "whole foot" analytical technique. The data demonstrates high levels of intra-trail variability as a result of variations in grain size, depositional moisture content, and the degree of sediment disturbance, all of which determine the bearing capacity of the substrate. Two trails were examined, which had consistent stride and step lengths, and as such variations in print topology were primarily controlled by substrate rather than locomotor mechanics. Footprint topology varies with bearing capacity such that firm substrates show limited impressions associated with areas of peak plantar pressure, whereas softer substrates are associated with deep tracks with narrow heels and reduced medial longitudinal arches. Substrates of medium bearing capacity give displacement rims and proximal movement of sediment, which obscures the true form of the medial longitudinal arch. A simple conceptual model is offered which summarizes these conclusions and is presented.

Bennett MR and Morse SA (2014). Fossilised Locomotion: What can footprints tell us? Springer.

Morse et al. (2013). Holocene Footprints in Namibia: The Influence of Substrate on Footprint Variability. American Journal of Physical Anthropology 151: 265–279.

As a foot makes contact with the ground, pressure is transfered through the foot into the substrate, deforming it if the applied pressure exceeds the strength of the substrate. In theory, higher pressures should correspond to greater depths and in this way we can infer something about the biomechanics of the track-maker.

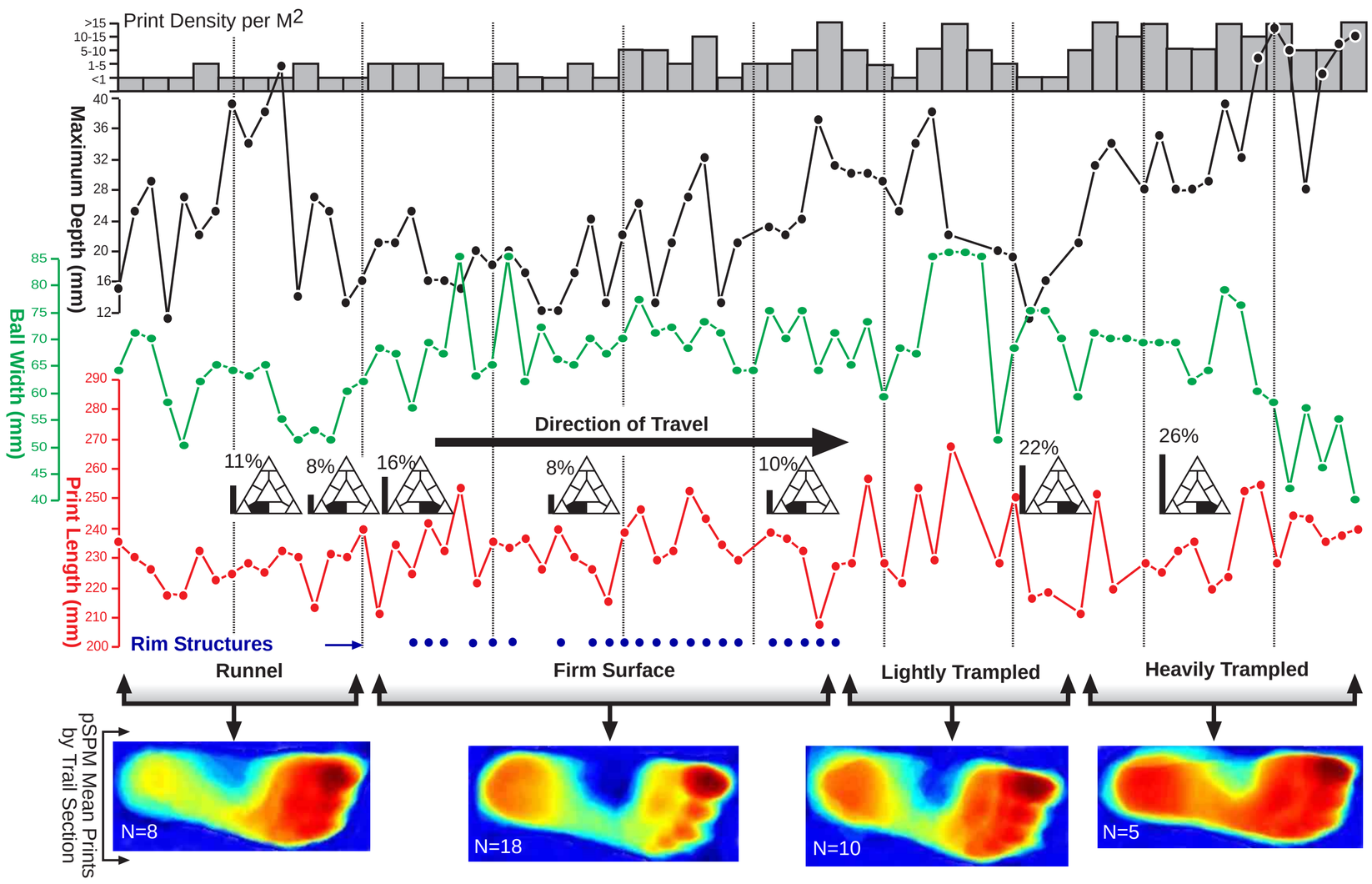
In practice this interaction is more complex and the substrate influences not only our gait but also the way in which it is encoded into the shape of a footprint. What we need are models of how track morphology (topology) changes with substrate.

Working in Namibia at a Holocene footprint site Bennett and colleagues have explored the control of substrate on track morphology. The tracks were formed between 500 and 1000 years ago in flood deposits contained by large dunes. The flood waters were used by wild animals and domestic herds and the silts contain a rich record of animal and human tracks. The site forms the perfect laboratory to study the influence of substrate on track formation. The research focused on two long trails made by two different track-makers and traverse a range of different substrates. Particularly important is the degree of prior animal trampling. This mixes the sediment destroying the natural stratigraphy of the silts and water is retained in the animal tracks, all of which leads to a much weaker substrate.

A view from above of the footprint surface showing Trail One. In trail is cut by a line of elephant tracks in the middle distance.

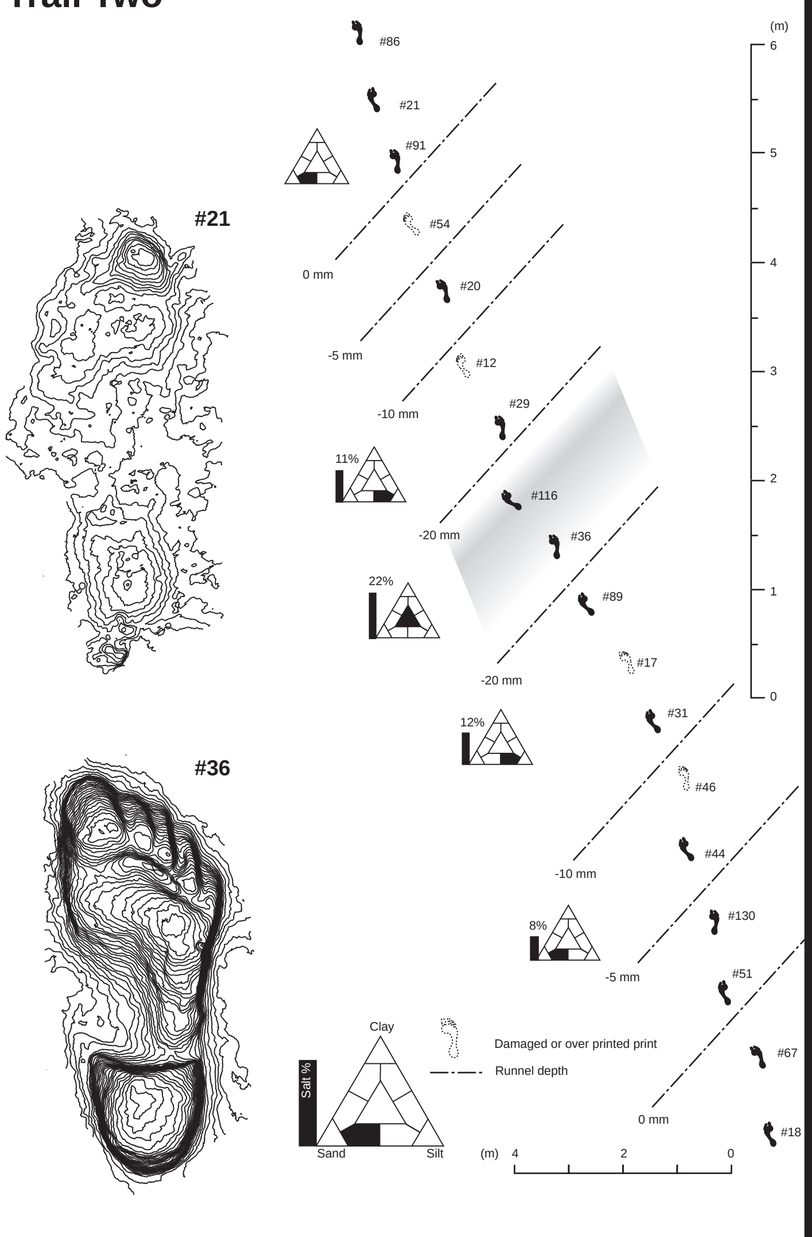
One of the tracks in the trail. Note the rain imprints in the photograph, formed by the impact of raindrops on the mud.

Trail One

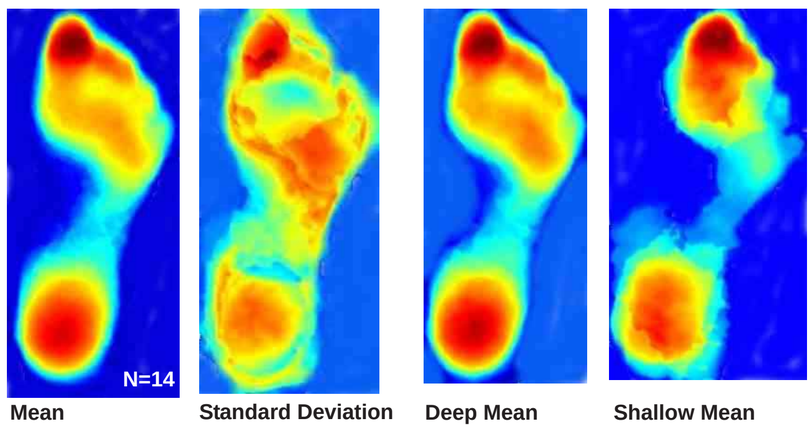


It is possible to divide Trail One up into several sections each with a different substrate character. For each of these sections a mean track has been determined and are compared above against some basic data. In the 'runnel' the substrate is of variable strength sometimes bearing the track-maker's weight and sometimes not; the deeper ball/toe area is typical of this. The weakest substrates occur in the 'heavily trampled' areas (prior to the track-makers passage) here the tracks have a different topology, with a narrow heel and a suppressed arch. The best and most representative tracks occur on the 'firm surface'.

Trail Two

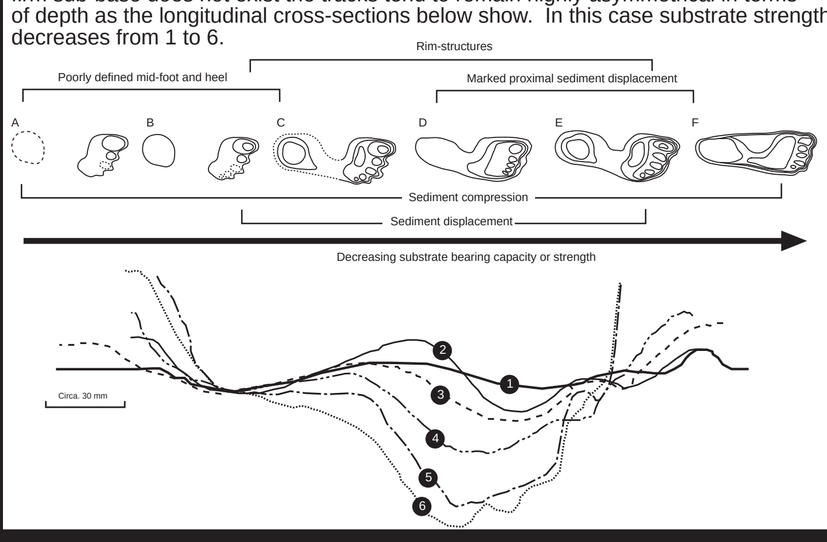


Shown below are the means for the tracks in Trail Two. Note the difference between the means for the 'deep' and 'shallow' tracks which correspond to weak and strong substrates respectively



Generic Model?

It is possible to use the data from Namibia to develop a generic model of how track topology varies with substrate bearing capacity (strength). When the substrate is firm only those areas of maximum plantar pressure are impressed and retained in the track. Normally this is around the first toe and medial ball area. As the substrate strength declines a profile with a typically asymmetrical (in depth) longitudinal cross-section develops; the substrate first holds the track-maker's weight, but fails further in the later stages of stance when maximum force is applied during toe-off. As the substrate become very weak the whole surface fails and the foot sinks until a firmer sub-base is reached. In this case that sub-base lies below the depth of animal trampling. If a firm sub-base does not exist the tracks tend to remain highly asymmetrical in terms of depth as the longitudinal cross-sections below show. In this case substrate strength decreases from 1 to 6.



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