Anthropic artifacts and donkey horseshoe traces looking like fossil human footprints: a case study from the Roccamonfina volcano (central Italy) with implication for human ichnology

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ABSTRACT - Fossil footprints of Middle Pleistocene hominids, locally known as “Ciampate del Diavolo”, were discovered in 2001 on the North-Eastern slope of the Roccamonfina volcano (central Italy, municipality of Tora and Piccilli, Caserta). The imprints occur on a surface of Brown Leucitic Tuff (BLT), dated to 349 ± 3 ka. After this discovery, e this tuffaceous formation was investigated in more detail on the North-Eastern, Eastern and South-Eastern side of the Roccamonfina volcano, with the aim of locating other fossil footprints. In 2003 another succession of nine hollows fully compatible with human fossil footprints for stratigraphic position, pattern and dimensional range was found on the same ridge but at a higher level. This second site, known locally as Cantarelle di Carangi, is positioned at a distance of about 1.8 km from the first fossiliferous area (municipality of Marzano Appio, middle-central Italy, Caserta province). Further surveys and archaeological excavations were carried out in the Cantarelle di Carangi site during 2008 to better understand, contextualize and confirm the potential ichnological value of the findings of 2003.

Ichnological and stratigraphical analyses, combined with findings during the excavations and historical data, however, tell a different story. What was supposed to be a new ichnosite with Pleistocene fossil footprints, is very likely the result of anthropic digging, erosion made by animals, and weathering. In any case, the discovery shows how careful researchers have to be in interpreting possible fossil footprints, especially in conditions of poorly preserved traces.

INTRODUCTION

In April 2003, during an extended survey along the North-Eastern side of the Roccamonfina volcano, within an area surrounding the Ciampate del Diavolo nearby site (Mietto et al., 2003), a succession of hollows, here called “α-trackway”, was noted by one of the authors (AP) and local inhabitants of Cantarelle di Carangi. The new site is located in the same formation (Brown Leucitic Tuff) and about 1850 m South-East, but at a higher level, than the Ciampate del Diavolo site (Fig. 1). These depressions have, at a first glance, a great similarity with the Middle Pleistocene human footprints from the Ciampate del Diavolo site (Mietto et al., 2003; Avanzini et al., 2008) both in dimensional range and in pattern data (Fig. 2). Further studies and surveys of the Cantarella di Carangi area were carried out during October and December 2008, attempting to further understand existing data and search for more new evidence. During these fieldworks some other track-like depressions, surrounding the “α-trackway”, were found within the Cantarella di Carangi area. However, their poor state of preservation and location within an ancient quarry-zone did not provide evidences to classify them as actual footprints. The tuff-ground is strongly weathered and none of the hollows found in 2008, just like the depression of the “α-trackway”, show clear anatomical details or other useful elements to demonstrate that the hollows are actual fossil tracks. This area has...
been actually exposed to prolonged and uninterrupted weathering and frequently visited by both quarrymen and chestnut farmers with pack animals in historical and recent times (Fig. 2).

Alignments of hollows and depressions similar to those we managed to survey and analyse are not rare in quarry areas and can be very misleading for scientific interpretation (Panarello et al., 2017), thus we have selected for study only the potential segment of trackway which really appeared as a possible human fossil trail. This trackway, the “α-trackway” (Fig. 2) is preserved in the same formation as the Ciampate del Diavolo trackway. $^{40}\text{Ar}^{39}\text{Ar}$ dating on the tuffs cropping out at the Ciampate del Diavolo provided an age of 349 ± 3 ka (Scaillet et al., 2008; Santello, 2010), placing this site in the Middle Pleistocene.

Here we discuss about the importance of a multidisciplinary approach to the study of human tracks, in order to find and to highlight objective evidences useful to distinguish actual fossil human footprints from pseudo-tracks even when they are located in the same geological formation and they are highly similar.

GEOLOGICAL SETTING

The studied area lies within an ancient tuff quarry known as Cava delle Cantarelle (Cantarelle quarry) present on the North-Eastern slope of the Roccamonfina volcano, not far from the small village of Carangi (Marzano Appio, Caserta). The Roccamonfina is a Quaternary volcano of central-southern Italy, located between the Roman Comagmatic and the Campanian regions, along the Tyrrhenian margin. The activity of the Roccamonfina began about 630 ka and ended around 53 ka (De Rita & Giordano, 1996) and it is commonly
subdivided into three main epochs (Rouchon et al., 2008): the first one at 630-385 ka, the second at 385-230 ka, and the third at 170-53 ka. The Carangi site is preserved on a layer of the Brown Leucitic Tuff, a formation associated to the second eruptive phase (Santello, 2009, 2010). The surface on which the potential human ichnites are preserved was dated by \(^{40}\)Ar/\(^{39}\)Ar method in the same way as it was done on the neighbouring Ciampate del Diavolo site and the result of this dating demonstrate the chronological equivalence of the two surfaces (349 ± 3 ka) (Mietto et al., 2003; Avanzini et al., 2008; Scaillet et al., 2008; Santello, 2010). Furthermore the two surfaces show also the same petrography and geochemistry (Santello, 2010). At Carangi site all eight units of the BLT succession (LS1 to LS8) are documented, whereas at the Ciampate del Diavolo only six of them occur. Moreover, in the Carangi site, all units are characterized by lithic fragments larger and more irregular than at the Ciampate del Diavolo (Fig. 3). All these data support the hypothesis that the Carangi site was closer to the volcanic emission point than the Ciampate del Diavolo site (Santello, 2009, 2010). Some of these units (especially those from LS3 to LS7) are strongly lithified by a zeolitization process. Aggregates of zeolite minerals (K-chabazite and phillipsite) cemented the matrix allowing the preservation of ichnites in the BLT formation.

**MATERIALS AND METHODS**

The succession of depressions, labelled “\(\alpha\)-trackway”, was georeferenced with a Garmin Etrex 10 (accuracy of ± 3 m) and entirely surveyed by detailed photogrammetry made by using Canon EOS 550D and Sony NEX 6 cameras. The pictures were processed with Agisoft Photoscan Pro and then scaled to obtain a photogrammetric 3D model of the surface, following the procedures of Mallison & Wings (2014). The mesh was then imported in Kitware Paraview to create high resolution depth maps, following the procedure of Belvedere et al. (2013). The parameters of each figured model are shown in Tab. 1, according to the method suggested by Lockley et al. (2015).

**RESULTS**

**“\(\alpha\)-trackway”**

**DESCRIPTION** - Nine aligned depressions interpreted as belonging to a trackway, the “\(\alpha\)-trackway” (Fig. 4), have been numbered in sequence from West to East from \(\alpha\)-1 to \(\alpha\)-9. The “\(\alpha\)-trackway” is narrow and sinuous and is entirely confined in a deep trough, which, in some parts, shows evident metal tool marks. All hollows of the track regularly alternate in the left/right positions with respect to a hypothetical medial axis. The length of the best preserved ones ranges between 20 and 27 cm, and their width ranges from 9.5 to 13 cm. The “\(\alpha\)-trackway” is flanked upstream by a clear break of the tuff-slope created by repeated cuts made by unknown quarry men for the extraction of tufa blocks for building purposes. The “\(\alpha\)-trackway” is also flanked downstream by a deep groove (30-40 cm wide and 60-80 cm deep), called “donkey trail” (Fig. 5).

No one of the hollows of the “\(\alpha\)-trackway” shows displacement rims. Starting from the most proximal limit of “\(\alpha\)-1”, the trackway develops toward the North-East for a total length of 4.44 m. The “\(\alpha\)-trackway” could join with a short segment of another trough which begins about 10 m away, roughly in the same direction. Such a segment descends towards the village of Carangi crossing the eastern side of the “Cantarelle” quarry area.

The slope of the “\(\alpha\)-trackway” is slightly ascending in the first 1.80 m from its starting point, then becomes descending, while the width of the trough varies from 28
cm (near “α-6” hollow) to 40 cm (near “α-2” and “α-3” hollows). Natural and anthropic alterations of the original tuff formations caused by an intensive and prolonged use of metal tools can be clearly seen everywhere in the inner and outer sidewalls of the “α-trackway” and of the general trough, but they are mainly evident at the upstream edge of the trace “α-2” and on the inner margins of the hollows from α-5 to α-9 (Fig. 6).

Anatomical details are not visible, neither in the 3D-scans nor in the high-resolution photogrammetry, thus measurements of the foot morphology could not be carried out. However, considering the straight-line distance between the proximal edge and the distal end of each hollow as a step, we can estimate that the step-length ranges between 44 and 58 cm.

“α-1”, “α-2” and “α-3” hollows (Fig. 7)

DESCRIPTION - The “α-1” hollow, though barely visible, is probably the hollow that most resembles the footprint of human left foot. It is 20 cm long and about 9.5 cm wide, and 2 cm deep. Areas of depression within this hollow are apparently localized in positions compatible with those of the heel and the ball of a human left foot, but there are no evidence of the toe. It is worth noting that every depression on the bottom of the “α-1” hollow appears more similar to a break and/or to an exfoliation of the original tuff ground due more to weathering, than to true pressure zones. Besides, each depression is surrounded by some small, randomly located ridges. Finally, there is a discontinuity along its lateral margin and there are no displacement rims. The “α-2”and “α-3” hollows cannot be objectively outlined because of the lack of clearly defined contours. The bottoms of the hollow show the same randomly located breaks and/or exfoliations of the original tuff ground described for the “α-1” hollow.

REMARKS - All mentioned features suggest caution in the identification of “α-1”, “α-2” and “α-3” hollows as true footprints because, although deteriorated, they do not show unequivocal evidence of pressures of human feet on a soft ground. They more truly look like natural/artificial depressions of the surface.

“α-4” hollow (Fig. 8)

DESCRIPTION - The “α-4” hollow lies in the position of a right foot. It is sub-rectangular, elongated in the direction of the movement, with a length of 22 cm and a width of 11 cm. The internal shape of the trace, with its regular depressions, vaguely resembles that of the human footprint. The hypothetical forefoot area is sub-circular and is diagonally crossed by the evident mark of a pointed metal tool (possibly a small pick), pointed out by white arrows (Fig. 8c).

REMARKS - The supposed hallux, too small compared to the size of the trace, actually is a hole left by a lava clast, enlarged by human activity. It is virtually impossible to refer the rises and the depressions in the middle-hollow to those of a medial arch.

Fig. 3 - Stratigraphical logs and correlations between the Carangi and Ciampate del Diavolo sites.
“α-5” hollow (Fig. 9)

Description - The “α-5” hollow lies in the position of a left foot, it is sub-rectangular, with a rounded heel, with the walls of the distal part absent, 25 cm long, and 13 cm wide. No internal details are visible. The sidewalls and the bottom of the depression show striations and holes that can be referred to the use of metal tools (especially chisels and small hoes), and therefore they are quite fully altered by the man-made cutting of the tuff.

Remarks - The lateral and medial margins of this trace are clearly rectified through the action of metal tools (chisels and/or horseshoes). Moreover, although it occupies a left position in the general pattern of the

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Tab. 1 - Parameters of the photogrammetric models.

Fig. 4 - The “α-trackway”. a) Zenithal photo. b) Contour-lines (step: 1 mm).
“α-trackway”, it appears deeper in its medial part and not in the lateral side as one could expect.

“α-6” hollow (Fig. 10)

**Description** - The “α-6” hollow lies in the position of a right foot. It is sub-rectangular, with a rounded heel, 25 cm long and 13 wide. As the previous hollow, also “α-6” is “open” in the distal part. No internal details are visible, but some parallel striae in the proximal part of the depression are clearly visible.

**Remarks** - The bottom and the sidewalls of this trace show marks by metal tools: the parallel striae are compatible with those left by horseshoe’s crampoons. Moreover, the right side of its lateral side appears very regular and, although no clear tool-marks are found, it is very likely that it was rectified by human activity.

“α-7” hollow (Fig. 11)

**Description** - The “α-7” hollow lies in the position of a left foot and is a sub-rectangular depression located on the upper edge of the trough, with a very linear left margin. No internal details are visible. The distal limit of the hollow is a big rounded and smoothed lava clast which is still in place and which is followed by a regular slight man-made excavation. The maximum width of this trace is 12 cm and the maximum length is 25 cm.

**Remarks** - The left margin of this trace is clearly rectified through the action of a metal tool (chisel and/or hoe) and no objective medial margin somehow referable
to a left footprint is visible. Finally, the lateral area of the hollow is too narrow and elongated to have been created by a pressure of a human foot.

“α-8” hollow (Fig. 12)
DESCRIPTION - The “α-8” hollow lies in the position of a right foot, and it is kidney-shaped with the concavity facing its the medial part. The maximum width is 10 cm and the maximum length is 25 cm.

REMARKS - The morphology of the hollow looks really like a human footprint, although the heel-strike zone and the hallux impression are no clearly preserved.

“α-9” hollow (Fig. 13)
DESCRIPTION - The “α-9” hollow is the deepest of the “α-trackway” and lies in the position of a left foot. This hollow has a maximum width of 12 cm and a maximum length of 22 cm. The bottom is corrugated and brownish,
Fig. 8 - Track-like hollow "α-4". a) Zenithal photo. b) Contour-lines (step: 1 mm). c) Depth map. Scale bar is 10 cm.

Fig. 9 - Track-like hollow "α-5". a) Zenithal photo. b) Contour-lines (step: 1 mm). c) Depth map. Scale bar is 10 cm.

Fig. 10 - Track-like hollow "α-6". a) Zenithal photo. b) Contour-lines (step: 1 mm). c) Depth map. Scale bar is 10 cm.
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and looks like smoothed by organic process of alteration. The contour-lines and depth map (Fig. 13b-c) show that the larger number of depressions is located in the medial part of the hollow, where in a human footprint there is the slight rise due to the plantar arch. Two longitudinal striae are evident on the wide and deep proximal margin: they are regular and parallel, with a spacing of six cm. No anatomical detail can be observed in the trace, whereas marks left by metallic tools and small areas of breakage are clearly visible, especially on the medial sidewall.

REMARKS - Longitudinal striae and bioglyphs produced by metallic tools suggest that “α-9” is unlikely a human footprint.

DISCUSSION

Taking into account the proximity of the “α-trackway” site to the Ciampate del Diavolo one (Mietto et al., 2003; Avanzini et al., 2008; Baucon et al., 2008, 2012) it was thought that “α-trackway” could really be a segment of a prehistoric pathway preserving some human fossil footprints. This hypothesis was initially supported by the fact that both sites are probably located on the same stratigraphic layer and by the succession of left and right track-like hollows, aligned in a very narrow-gauge trackway, which reminds an actual succession of footprints.

However, the lack of unequivocal morphological details within the footprints (e.g., plantar arch or hallux impressions), quite clear in the Ciampate del Diavolo site, the lack of displacement rims, and the fact that the “α-trackway” is within a quarry area, provided good insights that the traces might not be fossils, but recent man-made structures created to ease and to steady the movements of men and of pack animals.

Thus, these hollows are believed to have formed after the consolidation of the pyroclastic deposit and not necessarily when it was still mild and soft. Moreover, all preserved structures of “α-trackway” were surrounded by a variety of carved incisions associable to the use of various metal tools, especially picks and hoes (Panarello et al., 2017). The Carangi track-like structures, hence, can well be considered as new evidences in the record of the bioerosional structures with a high potential for future ethno-archaeological studies of the area (Baucon et al., 2008). Finally, a comparison of the “α-trackway”
with other similar rock structures located both in Italy and abroad (Panarello et al., 2017), strongly supports the hypothesis that the “α-trackway” is actually a man-made structure, created in historical age, altered by natural weathering and by human and animal activity on the site (Panarello, 2008; Panarello et al., 2017). A local 80-year old quarryman (Mario Rivalli), reported that donkey was the unique pack animal used both by quarrymen and by the farmers harvesting in the chestnut groves very common in the surroundings. No surprise, then, that during the excavation and cleaning of the site for the analysis of the tracks, a donkey horseshoe was found.

This horseshoe is 12.5 cm long and 8.5 cm wide (Fig. 14a) and provides the first-evidence of the size of the donkey hooves and of the horseshoes used by local people in historical time. The width is very important, because it is fully consistent with the width of the traces of the “α-trackway”, that range from 9.5 cm, where the hollows are deeper and the rampes walls more vertical, to 13 cm, where they are shallower. In addition, the hollows “α-6” and “α-9” show two parallel striae in their proximal border, matching in spacing (they are 6 cm distant) and configuration the crampons of the iron horseshoe discovered (Fig. 14). The step lengths of the “α-trackway” (range 44-58 cm) are compatible both with those of a human (Kim et al., 2008) or of a donkey.

CONCLUSIONS

In order to come to the conclusion that a hollow on the ground is a fossil trace, at least some basic conditions must be verified: 1) the hollow must be found within an environment in which taphonomic processes of preservation are possible; 2) the hollow must be located on the top-surface of a sedimentary layer; 3) the age of the layer must be chronologically compatible with that of the hypothetical trackmaker; 4) displacement rims must be visible on the borders of the hollow, to document that the hollow was caused by the emplacement of a still soft and...
not lithified surface; 5) anatomical details of the supposed trackmaker must be visible (Day & Wickens, 1980; Day, 1991; Berge et al., 2006; Bennett et al., 2009, 2010, 2013, 2016; Bromley et al., 2009; Morse et al., 2010; Raichlen et al., 2010; de Lumley et al., 2011; Meldrum et al., 2011; Bates et al., 2013; Bennett & Morse, 2014; Dingwall et al., 2013; Ashton et al., 2014; Masao et al., 2016; Panarello et al., 2017).

Therefore, on the basis of the features of the “α-trackway”, the most logical conclusion is that this track is actually a succession of hollows created by quarrymen and/or chestnut farmers to balance and steady the walking of pack animals. The severe weathering and erosion is explained by long lasting exposure (probably hundreds of years) in an environmental setting characterized by quarrying activities, harvesting and, by the end, moving of people and animals (Migliozzi, 2005; Panarello, 2008).

Summarizing, it is worth noting that:

1. “α-trackway” is recorded in the upper part of the Brown Leucitc Tuff, corresponding to the “LS7” unit of Ciampate del Diavolo site (Fig. 3; Santello, 2010), but at 487 ± 3 metres a.s.l. ⁴⁰Ar/³⁹Ar radiometric dating applied to samples taken from the surface of Carangi gave the age of 349 ± 3 ka (Santello, 2010), basically equivalent to that of the surface of the Ciampate del Diavolo site on which true and undisputed human fossil footprints (the so-called Ciampate del Diavolo) are documented. This latter site is located 1.815 km from Carangi site (Santello, 2010) at 296 ± 3 metres a.s.l.;

2. the gait pattern of the “α-trackway” hollows and their size do not differ from human fossil footprints reported in literature. This is true even if the same human-like footprints of the “α-trackway” do not preserve unquestionable and measurable anatomical details;

3. therefore, ichnological analyses must be always accompanied by thorough archaeological and sedimentological analyses, and integrated also with local historical studies of the human activities in the area (Panarello et al., 2017).

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