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Human footprints from Italy: the state of the art

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ABSTRACT - The ichnological record of human traces from Italy is rich and quite diversified. In recent years, the development and dissemination of various methodologies and technological applications has facilitated the re-analysis of this record, enabling different, sometimes deeper, interpretations favoured by the integration of external data, both geological and palaeontological. The oldest occurrence of the human ichnological record from Italy is represented by the Middle Pleistocene 'Devil's Trails' ichnosite in the "Foresta" area (Roccamonfina volcano, southern Italy), depicting human trackmakers trampling a pyroclastic flow deposit while descending a slope dating to about 349 ka. Most of the record is Holocene in age and is constituted by the Upper Palaeolithic Grotta della Bàsura site (Toirano, northern Italy, about 14 ky), the protohistoric sites of Afragola, Nola and Palma, the area of Pompei and the site of Aosta. The record is enriched by the ichnological evidence preserved in military structures of Trentino region (northern Italy) during the First World War. An updated report and discussion of these sites is provided here.

Keywords: human footprints; Pleistocene; Holocene.

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1. INTRODUCTION

The first study devoted to human fossil footprints in Italy was due to Leon Pales (Blanc et al., 1960) who, in the middle of the 19th century, analysed the Palaeolithic fossil footprints of the Grotta della Bàsura near Savona. Despite the frequent presence of human traces in archaeological contexts of Roman and medieval Ages (i.e. Acocella, 2013; Giorgetti and González Muro, 2011; De Vos and Maurina, 2011), the study of this type of traces played secondary role for decades. Only in 2003, after the correct interpretation by Marco de Angelis and Adolfo Panarello of the prints impressed on the ignimbrite of the Roccamonfina volcano near Caserta, the interest in this discipline has been renewed (Mietto et al., 2003).

In recent years, the attention to this type of finds has undoubtedly increased and the identification of new sites is linked to the review of historical ones. The use of modern investigative approaches led the re-examination of old finds and expanded the study of human traces in archaeological and historical contexts of the most diverse areas and ages (Avanzini, 2011) (Fig. 1).

2. THE PLEISTOCENE RECORD

2.1. THE 'DEVIL'S TRAILS' ICHNOSITE (ROCCAMONFINA VOLCANO, CASERTA, SOUTHERN ITALY)-MIDDLE PLEISTOCENE

The oldest evidence of human footprints from Italy is represented by the well-known 'Devil's Trails' ichnosite at Tora e Piccilli ("Foresta" area, Roccamonfina volcano, Caserta province, southern Italy) (Fig. 1). The ichnosite, formally described by Mietto et al. (2003), was already known by local people since the first half of XIX century (Panarello, 2005; De Angelis, 2009; Panarello et al., 2017a). The record consists of many footprints preserved on a volcanic deposit so as to evoke, over time, various fantastic and anecdotal interpretations about an uncanny walker able to cross fresh lava without getting burnt (hence the name "*ciampate del diavolo*", literally translated

Fig. 1 - Localization of the main sites with human footprints in Italy. 1) 'Devil's Trails' ichnosite (Roccamonfina volcano, Caserta); 2) Grotta della Bàsura (Bàsura Cave) site, Toirano (Savona); 3) Afragola, Nola and Palma Campania (Napoli); 4) Pompei Area (Napoli); 5) Aosta; 6) Valmorbia (Trento); 7) Celva Mount (Trento).

into "devil's footprints" or "devil's trails"; Avanzini et al., 2008; Panarello et al., 2017b), or an ancient warrior of historic times (Iulianis, 1986).

The record represented, for at least a decade, the oldest occurrence in the global human ichnological record, leading to a great scientific and media interest (Avanzini, 2003; Avanzini et al., 2003, 2008; Mietto, 2004, 2009; Mietto et al., 2013; Panarello, 2016a, 2016b; Panarello et al., 2017a, 2017b, 2018, 2020; Palombo et al., 2018; Saborit et al., 2019). Recently, evidence for older human footprints (likely referable to *Homo herectus*) have been described from Ileret/Koobi Fora in Kenya (Bennett et al., 2009), at Happisburgh in the United Kingdom (Ashton et al., 2014), at Gombore II.2 - Melka Kunture, Africa (Altamura et al., 2018). The human-like footprints from the Miocene of Trachilos (Crete, Greece) could have been produced by an ape that convergently evolved human-like foot anatomy (Gierliński et al., 2017).

The first ichnological survey in the 'Devil's Trails' ichnosite showed the existence of at least three main trackways, which were imprinted on a zeolite-rich deposit produced by a pyroclastic flow originally dated at 385,000-325,000 years ago. However, a new trackway and two other possible directions of walking have been recently announced raising the number of human trackways at least to four (Panarello et al., 2020). Moreover, some stone tools have been found within the site and in its close surroundings (Panarello et al., 2017a, 2020).

2.1.1. Geographic and geological settings

The "Ciampate del diavolo" site is located on the northeastern slope of the Roccamonfina volcano (N41°19.954'-E14°01.488') in the Roman Comagmatic Province (Appleton, 1972). The geological evolution of the Roccamonfina volcano comprises several activity phases (Giannetti, 1979a, 1979b; Radicati di Brozolo et al., 1988; Cole et al., 1992; De Rita and Giordano, 1996; Rouchon et al., 2008 and references therein). The ichnological record refers to the end of the first phase, when, between 0.385 and 0.335 Ma, a thick ignimbritic succession, known as "Brown Leucititic Tuff" (BLT - Luhr and Giannetti, 1987; Ballini et al., 1989a) was deposited on the slope of the main stratocone. The human and animal tracks are preserved at the top of the LS07 (*sensu* Santello, 2010) within the BLT (Avanzini et al., 2008; Santello, 2010; Panarello et al., 2017a, 2020), which is exposed for approximately 2000 m^2. According to Mietto et al. (2003), zeolitization (low temperature mineral neoformation) of the trampled deposits led to the lithification of the surface, thus enabling the preservation of the footprints. These were in turn covered by coarser, granular material belonging to the LS08 which further contributed to footprints fossilization (Santello, 2010; Panarello, 2016a, 2016b, 2020).

The first dating of LS07 based on K/Ar method provided an age of 385-325 ka (Appleton, 1972; Giannetti, 1979a, 1979b; Luhr and Giannetti, 1987; Radicati of Brozolo et al., 1988; Ballini et al., 1989a, 1989b, 1990; Cole et al., 1992; De Rita and Giordano, 1996). Subsequently, Scaillet et al. (2008) used the $^{40}Ar/^{39}Ar$ method providing a dating of 345±6 ka. The last available and probably best-accurate estimate is given by Santello (2010), which dated the trampled layer at 349±3 ka. According to this age, the ichnosite results a little bit younger than Termination IV and referable to the late MIS 10 (Panarello et al., 2017a, 2020).

2.1.2. Ichnology

After the first report stressing the global significance of the Roccamonfina site (Mietto et al., 2003), subsequent field work was conducted between 2005 and 2010, enriching the record from the village of "Foresta" (municipality of Tora e Piccilli, Caserta province) with other evidences of human frequentation, some of which are still under study (Panarello et al., 2017a) (Fig. 2).

Originally, at least 46 footprints and a single possible handprint organized in three trackways (A, B, C) were recognized together with other animal traces. 14 new human footprints have been recently announced from the site raising the total number of human traces to 81. These new findings allowed for the identification of another human trackway (called Trackway E) (Panarello et al., 2020).

A first detailed description of three main trackways, named 'Trackway A', 'B' and 'C' was given in Avanzini et al. (2008). Trackway A is made of 26 footprints on a total length of 13.40 m. Footprints depict an individual descending a very steep slope by crossing it through a

Fig. 2 - Foresta "Devil's Trails" ichnosite: southern overview of the trampled BLT-slope; a) Western overview of the prehistoric pathway P1; b) South-eastern view of Trackway A; c) South-eastern view of Trackway B; d) Western view of the segment 2C of Trackway C (scale-bar: 2 m); e) Eastern oblique 3D generated photo of Trackway E (scale-bar: 10 cm); f) Southern oblique 3D generated detail photo of the footprint B11 (left) preserving all the parts of a leg (calf, ankle an foot) (scale bar: 10 cm).

Z-shaped path, probably to choose the steadiest and most convenient gradient (Mietto et al., 2003; Avanzini et al., 2008; Saborit et al., 2019).

Trackway B consists of 19 footprints and a single handprint and has a total length of 8.60 m (altitude difference of 2.91 m); looking at the spatial disposition of the tracks, it seems that the producer placed its own feet in a more irregular manner than occurred during the impression of the 'Trackway A'; moreover, footprints show slipping traces very likely indicating that the individual descended the slope in a less deliberate manner (Avanzini et al., 2008).

Trackway C was recently reinterpreted (Panarello et al., 2020); the trackway is 10.6 m long and is composed of 13 human footprints composing two quite-straight segments, which are separated by a rupture of the ground extending for about 5.59 m.

Trackway E was described for the first time in Panarello et al. (2020). It is composed by four human footprints in regular right/left succession and has a total length of 1.10 m and a maximum width of about 17 cm. Trackway E indicates movement toward the west, which is in an opposite direction to all the others.

Trackways A, B and C are narrow and almost constant with respect to the pace and stride length, respectively equal to 60 cm and 120 cm. The stride length/footprint length ratio equals to 5. Footprints indicate both inward and outward foot rotation with respect to the trackway midline (i.e. foot angle), with values ranging from -5° to 20°, and a pace angulation ranging between 90° (final portion of Trackway A) and 160°, this last value mainly characterising trackways B and C (Avanzini et al., 2008). In Trackway E the average measurable step and stride are, respectively, 34.17 cm and 69.5 cm (Panarello et al., 2020).

From a morphological and functional standpoint, footprints are plantigrade, entaxonic, with an average length of about 24 cm and an overall width of about 10 cm, thus appearing relatively short and broad (Avanzini et al., 2008). The footprint E3 (Trackway E) is almost completely preserved and has a total length of 27 cm (Panarello et al., 2020).

Adopting a ratio equal to 15.5% and the available formulas for stature estimate (Grieve and Gear, 1966; White, 1980; Charteris et al., 1982), Avanzini et al. (2008) ascribed the footprints of Trackways A, B and C to adult individuals no taller than 1.56 m, walking at an average speed of 1.09 m/s (based on the method of Alexander, 1984). The footprints of Trackway E seem left by a taller individual (Panarello et al., 2020), resulting 174.2 cm tall.

Based on *Homo* fossil remains from the region (i.e. the Ceprano skull; Ascenzi et al., 1996, 2000; Manzi et al., 2000, 2010; Manzi, 2016; Di Vincenzo et al., 2017), Panarello et al. (2017a) considered that very likely the Roccamonfina footprints could be attributed to an European Middle-Pleistocene form like *Homo heidelbergensis*. Today, based on a renewed debate about the precise characterization of *Homo heidelbergensis*, it seems to be more correct to leave unaddressed the precise identification of the Foresta trackmakers. Nonetheless, the shape and the dimensional range of the human footprints of Foresta allow us to suppose that the hominins who walked on the Roccamonfina volcano slopes during the Middle Pleistocene were part of human populations widely diffused in southern Latium and shared some anatomical features with the Sima de los Huesos hominins (Panarello et al., 2020 and references therein).

More recently, further studies devoted to taphonomy, associated palaeoichnofauna and archaeology have been undertaken (Panarello et al., 2017a). The associated palaeoichnofauna is characterised by different tracks preserved on the sub-horizontal surface also trampled by humans (Panarello et al., 2017a). These tracks were referred to middle sized ruminant artiodactyls and possible young strait-tusked elephants (Panarello et al., 2017a; Palombo et al., 2018).

Panarello et al. (2017b) described the additional P1-Trackway located on the top of the same BLT (Brown Leucitic Tuff, top of layer LS7) zeolitized layer preserving the above described footprints, and representing the area from which the two trackways A and B start. The fossil pathway, called P1-Pathway (start: N41°19.954'-E14°01.466', ends: N41°19.962'-E14°01.496'), subdivided by the authors into 25 different segments, is characterised by a total length of ~53.19 m, showing a total width ranging from 1.40 m to a maximum of 3.21 m and registration across an area with an altitude varying from 292±3 m a.s.l. at the start (west) to 283±3 m a.s.l. (east). The authors recognized on the surface several superimposed human traces, some of which referable to the footprints forming trackways A and B, followed by a post-lithification smoothing of the traces linked by Panarello et al. (2017b) to the passage of both human and animals and, in historical times, to the quarrying activities and frequent foot traffic across the site. Based on an analysis of the global record, Panarello et al. (2017b) considered P1-Pathway as the oldest known human "pathway" in the world.

After the reports by Mietto et al. (2003) and Avanzini et al. (2008), which interpreted the purported handprint (TP_M1; Trackway B) as an intervention of the left arm to regain lost balance when sliding in the soft substrate, Panarello et al. (2018) re-analysed the track by means of high-resolution Digital Photogrammetry. The hand-print was interpreted as fully compatible with those characterising actual human hands. Based on general morphology and print length and width, the material corresponds well to the variability detected in anthropometric values for both Pleistocene hominins and present day humans (Mc Henry, 1992; Marzke and Marzke, 2000; Buryanov and Kotiuk, 2010; Garrido Varas and Thompson, 2011; Almécija et al, 2015; Darowish et al., 2015; Lorenzo et al., 2015) and correlates very well with previous stature estimates (Avanzini et al., 2008; Panarello et al., 2018). Thus in conclusion, the study confirms the original interpretation of the TP_M1 hollow as a handprint left by a bipedal Middle Pleistocene small hominine in the course of instinctive movements, necessary to regain the lost balance after a sudden long slide on the steep Roccamofina slope, also representing the oldest confirmed human fossil handprint known to date (Panarello et al., 2018) (Fig. 3).

Saborit et al. (2019) investigated the locomotor behaviour of Middle Pleistocene human trackmakers with regard to step length corrections while walking on a slope, applying a previous model (Saborit and Casinos, 2015) on stocky trackmakers (1.60 m in stature and 68 kg in body weight based on the authors estimation), compatible with Middle Pleistocene *H. heildebergensis* and *H. neanderthalensis* (Helmuth, 1998; Ruff, 2002; Carretero et al., 2012; Will et al., 2017), and especially with the values provided for the hominids at Sima de los Huesos at Atapuerca dated to 430 kyr (Arsuaga et al., 2014, 2015). The authors concluded that Middle Pleistocene trackmakers walked using a dynamic equivalent gait to that characterising modern humans, with gait adjustments during locomotion in order to minimize energy expenditure (Saborit et al., 2019). According to the authors, the body characteristic inferred from the footprints, along with the dynamic of walking, leave still open the debate regarding a putative attribution of the footprints to a given *Homo* species.

3. THE HOLOCENE RECORD

3.1. GROTTA DELLA BÀSURA (BÀSURA CAVE) SITE, TOIRANO (SAVONA, NORTHERN ITALY)-UPPER PALEOLITHIC

The Grotta della Bàsura (Bàsura Cave) site (Toirano, Savona, northern Italy) is prominent for preserving a unique record of human tracks and traces of Upper Paleolithic age (Fig. 1). The inner portions of the cave were discovered in 1950 by a group of young local people that broke a stalagmite column located few meters from the entrance (Tongiorgi and Lamboglia, 1954; Blanc, 1960; Lamboglia, 1960). Soon after the discovery, which constituted one of the most spectacular finding at that time regarding Italian prehistoric research (Giacobini, 2008), several preliminary studies were conducted to investigate both the archeological and ichnological evidence (Chiappella, 1952; Tongiorgi and Lamboglia, 1954; Blanc, 1960; Blanc et al., 1960; Lamboglia, 1960; Pales, 1960; De Lumley and Giacobini, 1985).

A renewed interest opened in 2014, when the Soprintendenza Archeologia Belle Arti e Paesaggio per la Città Metropolitana di Genova e le province di Imperia, La Spezia e Savona - Genova in cooperation with the Municipality of Toirano, promoted a new multidisciplinary investigation of the site involving archaeological, geoarchaeological, sedimentological, geochemical, ichnological and archaeobotanical analyses. The new studies, also supported by a National Geographic Grant to one of the authors (Grant EC-53477R-18 to M.R.), took advantage of new cutting edge methodologies and technologies (i.e. palaeosurfaces laser scans, geometric morphometrics and high-resolution digital photogrammetry), allowing re-interpretation of part of the record (Citton et al., 2017; Avanzini et al., 2018; Starnini et al., 2018; Romano et al., 2019) that is still under study. In particular, the most recent studies allowed the reconstruction of the activities of an Upper Palaeolithic human group inside the cave in the framework of a single exploration that occurred about 14 ky cal BP. For the first time in the global human ichnological record the evidence of crawling locomotion is reported (Romano et al., 2019).

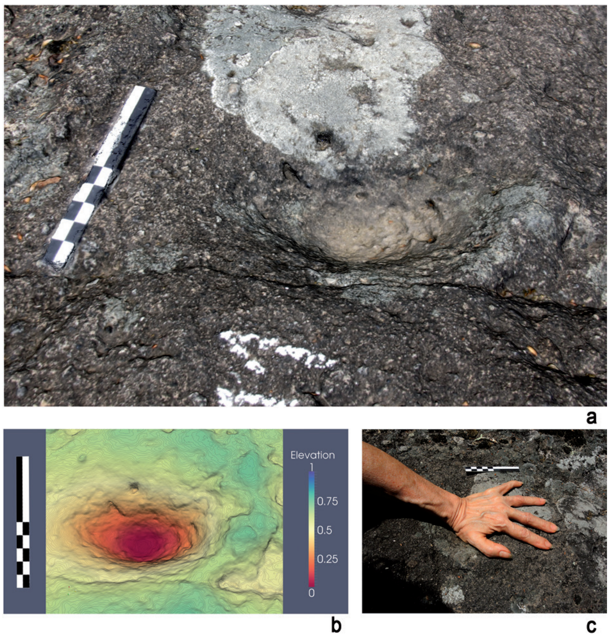

Fig. 3 - Foresta "Devil's Trails" ichnosite: a) 3D generated photo of the fossil handprint "TP_M1" along trackway (Western view); b) depth map (Western view); c) simulation (Southern view). (Scale bar: 10 cm).

3.1.1. Geographical and geologic settings

The entrance of Grotta della Bàsura is located at 186 m a.s.l., about 1 km north of Toirano (Savona, western Liguria) at the foot of Mount Carmo of Loano (436253.433 E; 4887689.739 N). The cave is characterised essentially by a sub-horizontal trend with a total spatial development of about 890 m and height difference of +20/-22 meters with respect to the entrance. The cave represents a portion of a broad larger karst system carved in a Middle-Triassic limestone-dolomite massif (Collina dei Roccai, 400 m a.s.l.), developed in the Costa Losera and overlain Dolomie di San Pietro dei Monti Fm., Anisian to Ladinian in age (Menardi Noguera, 1984). Recently, Chiesa et al. (2019) analysed the speleogenesis of the cave systems, correlating the formation of the karst system to the rising of mineralized waters and a weak thermalism. Four distinct levels were discovered in the karst system, with the upper hydrologically inactive one represented by the Grotta del Colombo (247 m a.s.l.) and the lower one by the Bàsura Cave (186 m a.s.l.). The system of cavities develops along NW-SE or WNW-ESE tectonic fracture and joints and along bedding planes.

Humidity in the Bàsura Cave is close to saturation all the year around, with air temperature constantly remaining around 16 °C (Bruzzone et al., 2006).

3.1.2. A brief history of the studies at Grotta della Bàsura

Virginia Chiappella was the first researcher ever to enter the cave in the early 1950s (Chiappella, 1952). She immediately recognized the great palaeontological and archaeological potential of the site, identifying several traces of human frequentation including footprints, digit tracks, lumps of clay adhering to the walls, along with abundant remain of *Ursus spelaeus* (Chiappella, 1952). A large part of human and other animal footprints were unfortunately damaged due to the uncontrolled access to the site by numerous visitors and in the construction of the present tourist pathway to make the cave site public (Blanc et al., 1960; De Lumley and Giacobini, 1985). It follows that only the traces covered by calcite concretions, or otherwise close to the wall, were not damaged and now represent the study material for the new multidisciplinary project.

The first formal ichnological study of the material was performed by Pales (1960) on 13 plaster casts of the best-preserved footprints. Pales recognized two principal human footprint classes on the basis of total foot length (22.5 cm and 27 cm on average, respectively) and, due to the apparent association with abundant remains of *Ursus spelaeus*, identified the putative trackmakers as 'Neanderthal-type' humans (Pales, 1960). Such interpretation has been subsequently falsified (De Lumley et al., 1984) and the first absolute dating that placed the human activity between 12,000 and 14,000 years BP (De Lumley et al., 1984; De Lumley and Giacobini, 1985), thus in the Upper Palaeolithic. More precise dating was subsequently provided on the base of radiocarbon dating of charcoal samples from the trampled surface, with a calculated age of human activity at 12,340±160 yr BP (calendric age calBP: 14,534±417) (Molleson et al., 1972; Molleson, 1985).

At same time as Pales's study, Blanc (1960) inferred that some individuals, also including juveniles, travelled into the cave and reached the innermost room, called 'Sala dei Misteri' (Mysteries room). The author especially focused on seven human heel traces left close to the main wall of the cave room, and interpreted as the evidence of putative prehistoric ritual activity, possibly involving young hunters in initiatory rites (Blanc, 1960). Such interpretation, according to Blanc (1960), was also supported by the presence in the room of a stalagmite, defined by the author as an 'acephalous sphinx' or a 'zoomorphic stalagmite', preserving a surface of great interest for intentional finger fluting-drawing, attributable to several individuals.

3.1.3. Ichnology

Recent surveys in the inner rooms of the cave led to the recognition of up to 107 human traces represented by both partial and complete footprints, handprints and several human body traces, including knee traces and others left by portions of the legs (Citton et al., 2017; Romano et al., 2019) (Fig. 4). The laser scanning of the cave rooms (see Romano et al., 2019) enabled researchers to obtain digital cross-sections of the environment and to contextualize the single 3D photogrammetric models in a broader digital environment (Citton et al., 2017; Romano et al., 2019), allowing comparison between the differential depth of impressions in the best-preserved footprints and inference of the dynamic of locomotion of the producers (Citton et al., 2017; Romano et al., 2019). In addition, Principal Component Analyses (PCA) conducted on the best-preserved footprints, allowed to obtain a two-dimensional scatter plot of all the morphological variability characterising the human traces, helping to identifying which variables most influenced the footprint-shape variation. The PCA conducted on anatomical foot landmarks proposed by Robbins (1985) led to the recognition of five clusters of human footprints (Romano et al., 2019). The analysis thus quantitatively suggests that a minimal number of five individuals entered and explored the Bàsura Cave in the Upper Paleolithic.

Based on the comparative analysis of all the results obtained with the above reported approaches and methodologies, Romano et al. (2019) recognize five distinct morphotypes, identifiable on the base of both dimensional and morphological features. Morphotype 1 is represented by footprints with an average total length of 13.55±0.49 cm, characterised by a poorly-developed plantar arch and a heel area that is in proportion broader than in longer tracks, thus indicating, along with total size, an early ontogenetic stage for the trackmaker. Morphotype 2 shows great variability due to different substrate conditions (see Webb et al., 2006; Morse et al., 2013). It is represented by footprints with a total length of 17±00 cm, characterised by a more pronounced plantar arch with respect to the condition observed in Morphotype 1. Morphotype 3 comprises footprints with a total average length of 20.83±0.51 cm and with a pronounced plantar arc, as highlighted by a strongly convex outline on the lateral margin coupled to an appreciable medial embayment. Moreover, this Morphotype shows a strongly adducted digit I trace and a consistent separation between adjacent digit couples II-III and IV-V. Footprints falling into Morphotype 4 have a total length of 22.80±0,42 cm and are characterised by parallel digit traces and by a less pronounced medial embayment if compared with the condition observed in Morphotype 3. Morphotype 5 includes the largest footprints to date recovered from the site that result in general more robust when compared to Morphotypes 3 and 4; footprints have an overall average length of 25.73±0.45 cm, with a variably pronounced plantar embayment and margins that result only slightly concave. Orientation of digit traces is comparable to the condition in Morphotype 4, while the adducted digit I resemble closely the condition described for Morphotype 3.

Fig. 4 - Selected traces form the Bàsura Cave (Savona). C33) Human footprint referred to the Morphotype 3 ('lower corridor'); SM15) human footprint referred to the Morphotype 3 ('Sala dei Misteri'); CA8) human footprint referred to the Morphotype 3 ('upper corridor'); C72) hand print ('lower corridor'); SM44) finger traces ('Sala dei Misteri'); SM55) finger flutings on the clay floor ('Sala dei Misteri'). .

Some footprints referred to Morphotypes 3, 4 and 5 are associated in the main gallery to sub-circular traces, interpreted as knee imprints, also associated in some cases with fore foot traces (Fig. 5). On the same trampled surface at least six isolated handprints, variably preserved as didactyl, tridactyl and pentadactyl prints were recognized. Such footprints have been interpreted as traces produced unintentionally by the trackmakers during both stance and progression phases while exploring the lower corridor (Romano et al., 2019). The heel traces already reported and discussed by Blanc (1960) were also considered. Their overall mean width is about 5.67±0.12 cm, a size comparable to the condition described for Morphotype 2 (Citton et al., 2017).

Stature, weight and ontogenetic stage of the putative trackmakers have been reconstructed for each morphotype (see Citton et al., 2017; Romano et al., 2019) on the base of eight terminal Upper Palaeolithic adult individuals from the Italian Peninsula (Corrain, 1977; Paoli et al., 1980; Formicola et al., 1990; Mallegni and Fabbri, 1995; Mallegni et al., 2000). The obtained foot length/stature ratios are 0.154, a value fully compatible with those proposed by Topinard (1878) and Robbins (1985) for modern humans living in between the XIX and XX centuries. Ages and stature reconstructions are as follows: a child three-year-old and about 88 cm tall corresponding to Morphotype 1; a child about 110 cm tall around six years old, corresponding to Morphotype 2; a pre-adolescent about 135 cm tall, probably between eight and eleven years old corresponding to Morphotype 3; a sub-adult to adult about 148 cm tall corresponding to Morphotype 4; and a 167 cm tall adult corresponding to Morphotype 5. Stature estimates for the latter have also been corrected and confirmed by the inferred length of the tibia derived from the study of the crouching trackway (Romano et al., 2019). The results obtained for the putative adult individuals, namely Morphotypes 4 and 5, are fully comparable to the stature inferred for European Upper Palaeolithic people, considered to average 162.4±4.6 cm for males and 153.9±4.3 cm for females (Villotte et al., 2017). The arch angles indicate a possible attribution to a male individual for the largest footprints, whereas for Morphotypes 1, 2, 3 and 4, no definitive gender attribution is possible, even if Morphotype 4 most probably represents a female individual (Fig. 6).

Along with the footprints, finger flutings are present in several parts of the cave, with the best-preserved ones from the inner "Sala dei Misteri" (Mysteries Hall). Finger flutings preserved on the terminal wall were classified as both Rugolean and Mirian, following the classification proposed by Sharpe and Van Gelder (2006) (Fig. 4, SM55). The great concentration of finger fluting is reported from the stalagmite concretion ('acephalous sphinx') briefly mentioned above, with traces essentially referable to the Mirian type and left by at least two different trackmakers, who smeared soft clay on the surface of the concretion. Traces made on the upper and middle portion of the stalagmite concretion can be referred, based on size, to an adult individual; by contrast, smaller traces on the base of the concretion can more likely be ascribed to a young individual, but such evidence is currently under study. More interesting evidence from the inner Sala dei Misteri are pits and holes excavated on the clay substrate, and at the moment preliminary interpreted as deliberate digging performed with the goal, probably connected to clay collecting, to make the finger fluting traces on the above reported stalagmite concretion.

The integration of different methodologies favoured the reconstruction of the complex exploration in the Bàsura Cave around 14 ky cal BP (Romano et al., 2019). The authors inferred that 159 m after having entered the cave and a climb of 12 m, the group reached the lower corridor ("Corridoio delle Impronte"), which preserves the large number of analysed footprints. The group walked essentially in a single line with the adult ahead followed by younger individuals in the trail; they most probably kept themselves close to the cave walls, acting a cautious attitude as when exploring dark and unknown environments. After about 10 m in the corridor the roof of the cave drops below 80 cm, so the members of the group were forced to get down on all limbs and to crawl, leaving the traces of both knees and hands on the soft substrate. The adult individual leading the group stopped about after few meters, likely in deciding the subsequent sequence of movement and left two parallel calcigrade footprints, then proceeding across the section where the roof is at his lowest point, also followed by the rest of the group. The group descended along a steep surface for about ten meters, and traversed a small pond were they left very deep impressions (still under study), and climbed again up a 10 m slope to finally arrive to the innermost "Sala dei Misteri", where they stopped for a short time. Once in this room, the adolescents and children collected clay from the cave floor and smeared it on the stalagmitic concretion ('acephalous sphinx' or 'zoomorphic stalagmite') at different levels, according to their height. In the same period the ten clear heel traces were formed close to the wall, interpreted as calcigrade tracks left by individuals collecting and manipulating clay on the floor, as already observed and inferred for the 'Salle des Talons' at Tuc d'Audoubert cave (Pastoors et al., 2015). Considering the large number of tracks left in this phase, the group had to stop for several minutes in the inner room, and before they reached the exit following a path in some sections different to the one followed on entry. Based on the footprint orientations and cave topography, they chose to cross, after the pond, the upper corridor instead of the lower one, maybe considering it as a safer and more comfortable pathway (Romano et al., 2019).

The multidisciplinary study indicated the hunters-gatherers behaviour should not always be put in relation to subsistence or practical necessity, but also could represent non- utilitarian activities, as also confirmed by diverse ethnographic evidence. The study also confirmed that children younger than 3 years old were following the rest of the group also in dangerous and social activities

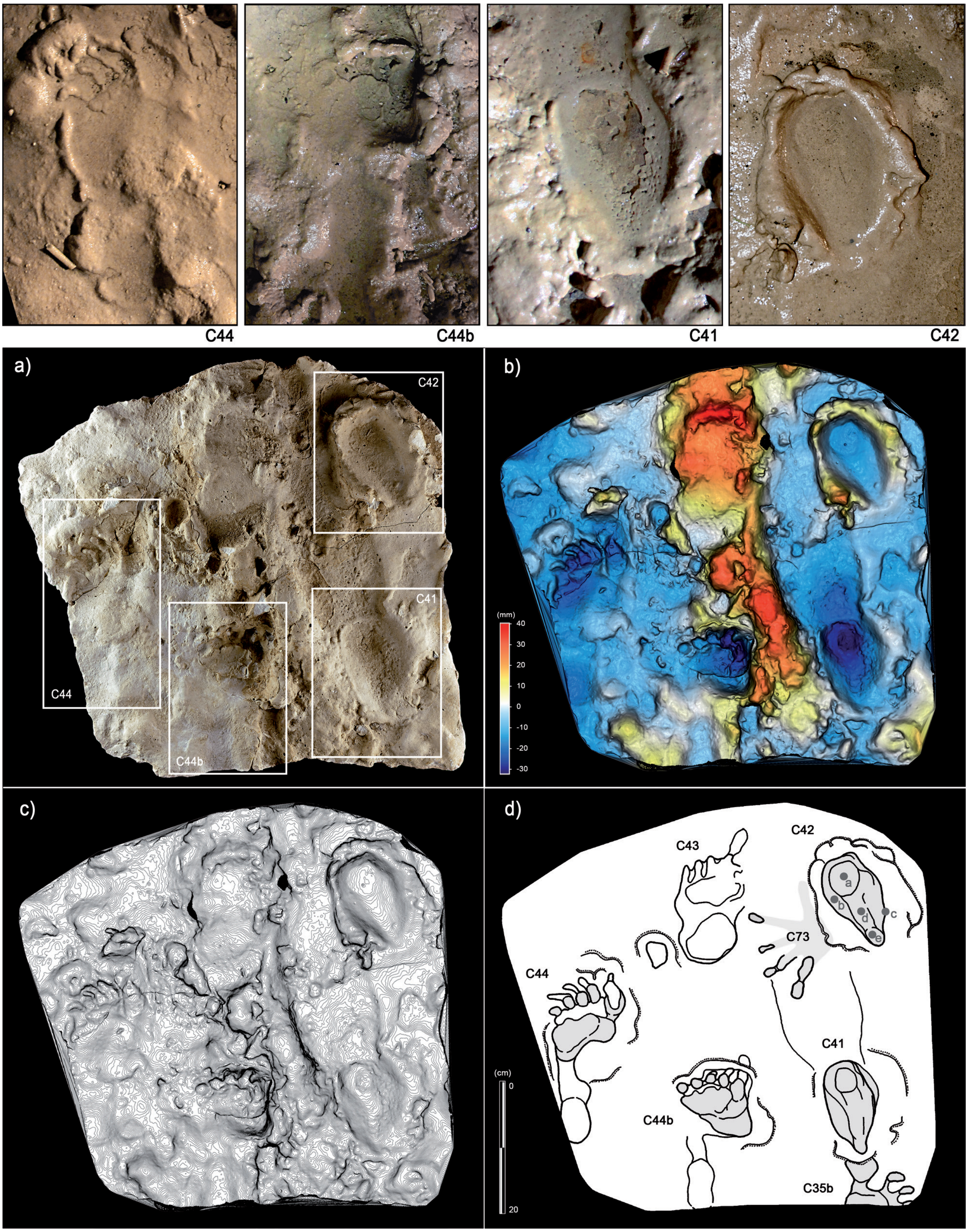

Fig. 5 - Selection of semi-plantigrade and knee traces from the 'lower corridor' of the 'Corridoio delle Impronte' in the Bàsura cave, indicating crawling locomotion of the producers. Semi-plantigrade and metatarsal traces (C44 - C44b) and knee traces (C41 - C42) imprinted on a plastic, waterlogged muddy substrate. a) Cast from the 1950s reproducing two knee (C41, C42) and two metatarsal (C44, C44b) traces; b) Digital Terrain Model obtained from the HDI 3D Scanner; c) topographic profile with contour lines, obtained from b; d) interpretive draw. In the knee trace C42 are located the impressions of: patella (a), *vastus medialis* (b), fibular head (c), patellar ligament (d) and tibial tuberosity (e).

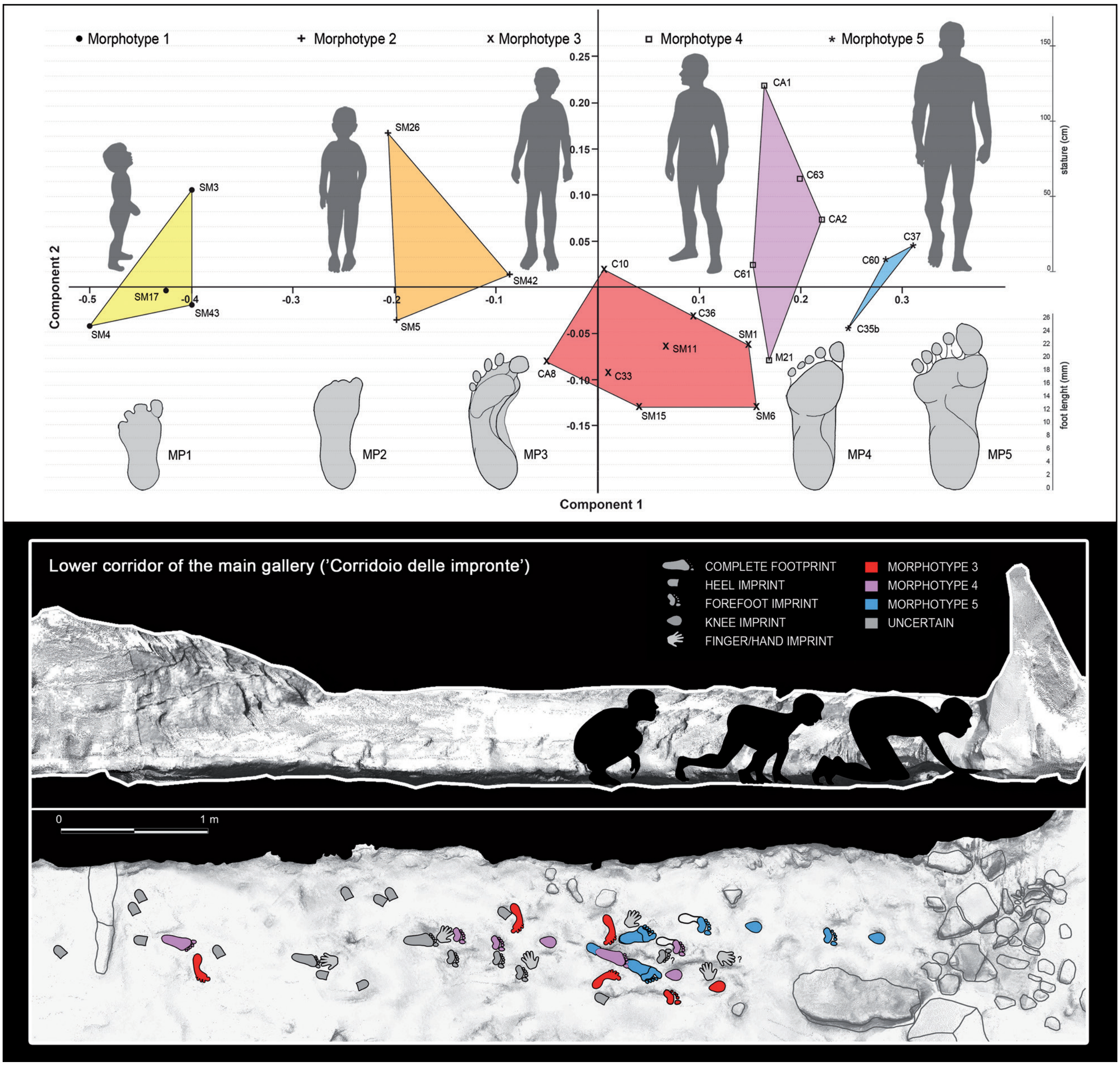

Fig. 6 - Principal Component Analysis (PCA) based on the best-preserved footprints from the Bàsura Cave and reconstruction of crawling locomotion in the "Corridoio delle Impronte". The five morphotypes to which footprints have been referred are shown.

and thus were in all respects active members of the Upper Palaeolithic populations (Citton et al., 2017; Romano et al., 2019).

3.2. AFRAGOLA, NOLA AND PALMA CAMPANIA (CAMPANIA REGION, SOUTHERN ITALY)-HOLOCENE

The protohistoric villages of Afragola, Nola and Palma Campania (southern Italy, Campania region) are vivid examples of the culture and everyday life of the oldest populations of Campania region (Fig. 1). They were affected by the volcanic phenomena that preceded and followed the great eruption of the Summa/Vesuvius commonly called "Eruzione delle Pomici di Avellino" or, simply, "di Avellino" (Mastrolorenzo et al., 2006; Di Vito et al., 2009). When the ancient inhabitants of the "Piana Campana" realized that the eruption had begun, they went away in mass with their animals walking on wide layers of ash created by the surge cloud. Thousands of human and animal footprints were thereby preserved on a first layer prior to the massive eruption and the collapse of the eruptive column with consequent pyroclastic flows. In the first layer, wooden elements and remains of other non-carbonized plants were found. This testifies that the levels created by the surge-cloud had a relatively low temperature, so that people who chose to run away did not suffer serious harm (Mastrolorenzo et al., 2006).

3.2.1. Geological setting

Deposits formed by this violent Plinian eruption have been dated to 3780 yrs BP by 14C (Mastrolorenzo et al., 2006; Di Vito et al., 2009) (Fig. 7a). At least two trampled layers have been surveyed: the layer already described as created from the ashes of the surge and those created by the pyroclastic flows and the following floods and lahars (Mastrolorenzo et al., 2006). The first footprints during the mass exodus were filled by the lightest materials of the eruption (white/grey pumices, lapillus, ashes) thus being preserved from the pyroclastic impetus and from the following hydrogeological events (acid rain, lahar, etc.) (Mastrolorenzo et al., 2006). As some flood and lahar deposit preserves some fossil footprints, it has been

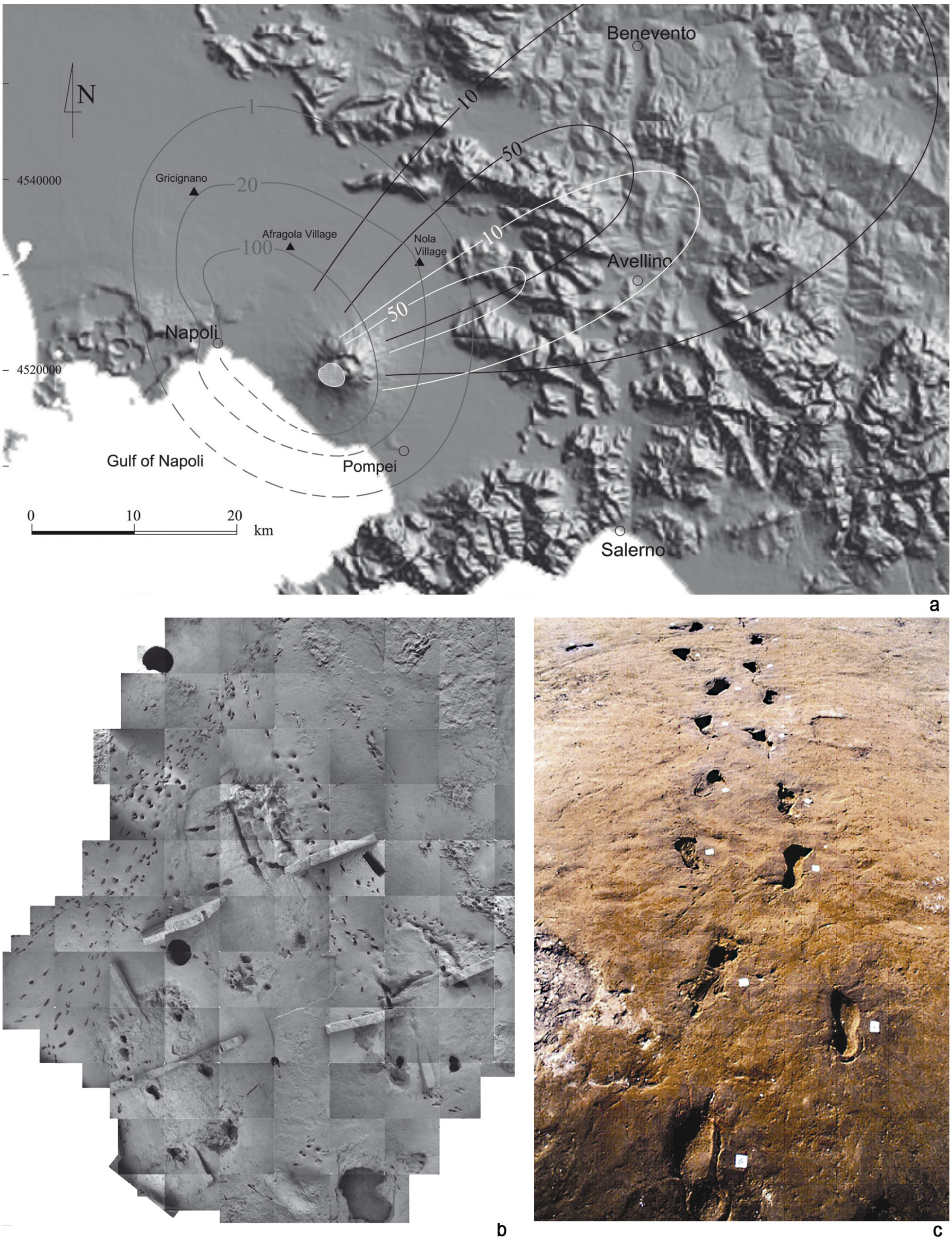

Fig. 7 - The Campanian plain showing Vesuvius, the Afragola Bronze Age village and the distribution of Pomici di Avellino deposits (a). Isopachs in cm, Eruptive Unit 2: white; Eruptive Unit 3: black, Eruptive Unit 5: dark grey (after Di Vito et al., 2009); b) Aerial view of the footprints made during the eruption and traces of three storehouses (after Laforgia et al., 2009); c) Footprints of two fugitives in the surge ash deposit found ≈15 km NNW of Vesuvius: thousands of footprints directed NNW away from the volcano testify to an en masse exodus from the devastated zone (after Mastrolorenzo et al., 2006).

inferred that human and animal exodus continued also during ash-fall and after the storms of rain and the floods (Mastrolorenzo et al., 2006).

3.2.2. Ichnology

The best investigated village, from a paleo-ichnological point of view, is Afragola (Giampaola et al., 2007). However, the collected data and the geo/ichnological evidence is almost the same as for other surrounding sites for a radius of at least 15 km. In these areas, thousands of human and animal footprints have been found on various depositional levels both inside and outside villages (Fig. 7 b,c). The footprints within the boundaries of the ichnosite of Afragola are mainly human and are randomly organized and concentrated around huts. Overlaps, slips, sudden changes of direction and jumps are common and clearly visible everywhere. The tracks, which are oriented away from the village for distances of up to 1 km, are oriented in various directions (Laforgia et al., 2009). Given the large number of human footprints, palaeo-ichnological measurements were carried out on a sample located in a small area outside the village. Referring to the human remains found in the nearby village of San Paolo Belsito, the sex of which is also known, sample imprints were attributed to 13 individuals whose stature supposedly did not exceed 1.40 m. These individuals have been considered as non-adults or children of unidentifiable sex. Other footprints have been attributed to 57 individuals whose estimated stature ranged from 1.40-1.70 m. The footprints of 9 other individuals suggest estimated stature exceeding 1.70 m so that they were attributed to adults of unknown sex. The speeds calculated from footprints vary from 2.5 to 5.4 km/h in 89.6% of the sample (Laforgia et al., 2009).

Animal footprints are associated with human ones. They were left by cattles (*Bos taurus*), sheep and goats, Equidae (both donkeys and horses), cats and dogs. Tracks of deers, porcupines, squirrels, and other rodents have also been identified (Laforgia et al., 2009).

3.3. POMPEI AREA (CAMPANIA REGION, SOUTHERN ITALY)-HOLOCENE

In Moregine, a small village located near the Sarno river, about 600 m south of the walls of the ancient city of Pompeii, remains of a majestic Roman villa were found in 1959 (Fig. 1). The villa was destroyed by the same eruption that buried Pompeii and therefore can be dated back to 79 AD. Its magnificently preserved frescoes, with many of the unearthed furnishings, are shown in a permanent exhibition created in the "Great Gym" of ancient Pompeii. Here, some casts of three footprints of human bare feet are exposed. The arrangement of the footprints suggests they could not belong to the same trackmaker. The casts of the footprints were made with plaster castings, so that the data that were possible to survey must be considered mostly approximate. The dimensions of the two entire footprints are as follows: right foot - length 24.5 cm, width 11.6 cm, left foot - length 24.6 cm, width 10.5 cm. Both footprints show a very raised and well-defined plantar arch, which demonstrate that they were left by unshod feet. It is not known whether the footprints on display were the only ones to be found, as no scientific publication has been dedicated to this ichnological discovery (Panarello, 2016b).

3.4. AOSTA (NORTHERN ITALY)-HOLOCENE

Archeological excavations during June 2014 in an area occupied by the former gym of the CONI (National Sport Federation) brought to light a series of attendance plans related to agricultural activities (Regione Valle d'Aosta, 2015; Panarello, 2016b; Amirotti et al., 2017) (Fig.1). On the last of these levels, a series of footprints of at least two adult and a child are documented, as well as a series of animal footprints (Fig. 8). Stratigraphic analysis placed these traces into the second Iron Age (5^{th}-1^{st} century BC). The available data show narrow tracks with aligned step sequences of apparent barefoot individuals still under study.

3.5. FIRST WORLD WAR SOLDIER TRACKS FROM THE VALMORBIAWERK AND FROM OTHER MILITARY STRUCTURES IN TRENTINO- ALTO ADIGE REGION (TRENTO, NORTHERN ITALY)-HOLOCENE

Avanzini et al. (2011) and Avanzini (2012) described several boot tracks detected on the floor of tunnels and trenches of the First World War in the Trentino-Alto Adige Region (Northern Italy). These traces represented the first report of footprints left by First World War soldier tracks, and were used to throw light on everyday life activities carried out in the underground bunker systems.

3.5.1. The Valmorbiawerk (Vallarsa, Trento)

The Valmorbiawerk, known as Forte Pozzacchio in Italian documents, is placed on the right side of the Vallarsa Valley, at about 8 km from Rovereto in the Trentino-Alto Adige region, at an altitude of 882 m a.s.l. (Fig. 1). The fort pertains to a system of fortifications planned at the beginning of the twentieth century by the Austro-Hungarian Empire, scared that Italy would try to obtain further territory in the Veneto Region (Fontana, 2004; Righi and Leonardi, 2006; Avanzini et al., 2011). However, by the beginning of First World War in July 1914 the structure was incomplete and when Italy enter the war on January 30^{th}, 1915 all the works in the fort were abandoned. The 80^{th} regiment of the Italian infantry occupied the fort on June 13, 1915, but the structure was recaptured by the Austro-Hungarian troops in May 1916 by the Strafexpedition, and controlled until the end of First World War (see Avanzini et al., 2011).

3.5.2. Ichnology

The boot tracks are preserved in one internal cave of the fort, likely dedicated to storage room, and are impressed on a 30 cm wide concrete curb which constitutes the

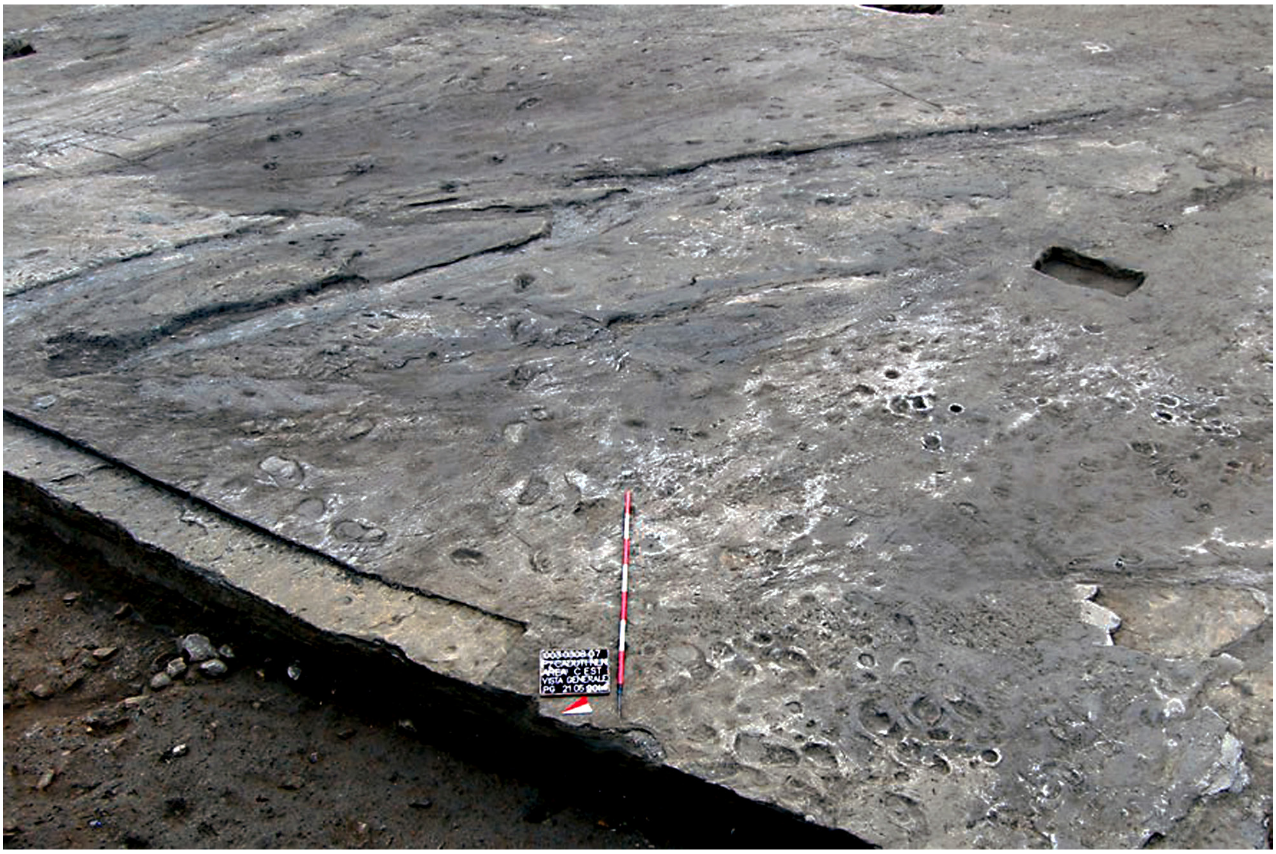

Fig. 8 - Archaeological excavation of the new hospital in Aosta. Human and animal footprints on a palaeosurface of the second Iron Age (after Amirotti et al., 2017).

perimeter of the room and raised 40 cm from the floor. On the top of the curb is a 2-3 mm thin layer of pure cement on which the boot tracks were impressed and preserved (Avanzini et al., 2011). The authors recognized a series of four walking patterns with a total length of 5.60 m, with an oblique pace length of 78-80 cm, a stride equals to 154-160 cm and a pace angulation ranging between 175° and 180°; the foot angle is outwardly rotated between 15° to 20°. General morphology, and in particular the hobnail layout, led the authors to refer all the tracks to the left and right boots of a same individual (Fig. 9 a-d). In all the studied traces, the heel region results the deepest impressed, due to the presence of a reinforcement made by rectangular and square-shaped hobnails. Comparing all the analysed footprints, Avanzini et al. (2011) were able to reconstruct the whole hobnail pattern of both left and right boots (Fig. 9e). In particular, the rim of the sole and heel were characterised by a close arrangement of nails with a rectangular base; around the tip the nails were uniformly and closely arranged in a group of 15, and disposed in pairs along the sides. The sole was differently characterised by semicircles of quadrangular hobnails, and another series that were aligned according to the foot main axis.

As stressed by Avanzini et al. (2011), the use of footwear reinforced with hobnails was common in the Alps until the 1950s and such features characterize the boots of soldiers in First World War in both Austro-Hungarian or Italian mountain troops. However, the peculiar pattern of hobnails disposition on the sole depends strictly on the nationality and branch of the armed services. Avanzini et al. (2011) have been able to ascribe the recognizable pattern to mountain footwear used by the Austro-Hungarian army (Bergschuhe) like other footprints recovered in several First World War mountain trenches (Luserna-Oberwiesen, Monte Nagia-Grom, Pasubio) (Avanzini, 2012) (Fig. 9g). Based on the inferred foot length of about 27 and 27.5 cm, and using the ratio provided by Topinard for foot length/height of 15% (Helmuth, 1974) and the values of 13.47% and 15.98% proposed by several authors (Burke, 2002; Fessler et al., 2005; Brenda and Rohreni, 2006; Kumar et al., 2007), Avanzini et al. (2011) reconstructed a possible height for the trackmaker of about 1.77-1.80 m; this is also in accordance with the value calculated starting by the length of the reconstructed shoe (shoe length/stature ratio of 16.63%; see Giles and Vallandingham, 1991; Ozden et al., 2005; Brenda and Rohreni, 2006).

Based on general structure and preferential wear evidence from the traces, Avanzini et al. (2011) reconstructed a quite normal locomotion pattern, characterised by a slight lateral foot functional prevalence (Fig. 9f); the evidence allows reconstruction of a possible trackmaker as a slender tall soldier showing a slightly

Fig. 9 - Valmorbiawerk fort site (Trentino-Alto Adige). a) Single well-preserved left boot tracks; b) partial right footprints; c) footprint heels with sliding track; d) superimposed trackways; e) the two reconstructed soles as seen from below; f) traces of use recognizable in the right foot ; g) Austro-Hungarian troops' mountain footwear sole (Bergschuhe).

varus knee, with a weight around 70-80 kg based on the formula proposed by Robbins (1985, 1986), and proceeding at a speed around between 1.67 and 1.80 m/s based on Alexander (1984). The individual very likely left the footprints in the fresh concrete between spring 1914 (beginning of the work in the secondary tunnels) and May 1915 (end of the works; see Fontana, 2005).

3.5.3. The military kitchens of Monte Celva, Trento

The fortified complex of Monte Celva, located immediately east of the city of Trento, was part of the defensive belt of the Trentino capital developed by the Austro-Hungarian Military Engineer in the second half of the 1800s (Fig. 1). From autumn 1914 until spring 1916 the city was surrounded by a formidable entrenched field network and equipped with walkways, concrete casemates and batteries dug into the rock. Monte Celva (998 m a.s.l.) was completely fortified with an articulated system of entrenches and tunnels that connected artillery casemates and steel dome pieces to which an efficient logistic system consisting of deposits, dormitories and warehouses, was associated. The work, which began at the dawn of the conflict and continued throughout the first year of the war, involved hundreds of local workers. In the autumn of 1915 there were 1538 workers, including 714 prisoners. The batteries had a staff of eight officers and 243 soldiers to which could be added another 16 officers and 900 soldiers housed in the warehouses of Pramarquart not far away, and almost 1500 men of reserve troops in case of need. It is clear that with a number of men of this magnitude the field kitchens in which meals for workers and soldiers were prepared were in full swing while the preparatory work was still going on around them.

3.5.4. Ichnology

Several human and animal footprints are preserved on the concrete floor of one of the Monte Celva kitchens. Three cave entrances open onto an entrenched courtyard protected downstream by a concrete wall. Of the three galleries, one was the kitchen, with the others intended for housing and storage. A corridor allowed the internal connection to the warehouse caves: dozens of different sizes and types of footprints are imprinted on its floor. The most abundant footprints correspond to shoes with soles covered by regular rows of nails with a rounded head and the heel reinforced by a sturdy metal plate (Fig. 10a). These are elongated soles ending with a relatively pointed profile. The same type of footprints is preserved in the galleries of the fort of the Sommo alto (Folgaria) (Avanzini, 2012). They are 28 cm long and correspond to the right and left foot of the same individual who moved irregularly from the kitchen to the warehouse. Using the methods already described above, it appears to have been about 168 cm tall and weighing just over 65 kg. More squat shoes, with a quadrangular tip and with rows of large and small nails alternating and aligned in transverse rows with respect to the sole, are imprinted on the lateral edge of the connection tunnel (Fig. 10b). They are two right footprints both oriented from the warehouse towards the kitchen. The heel is raised and the weight of the author's body (about which, however, it is not possible to say much) is unloaded all over the front of the foot. Among them, preserved in several points on the floor, the traces of a small mammal are recognizable. Four elliptical digit traces are placed in front of a heart-shaped plantar pad. More rounded outline footprints are associated with more elongated ones suggesting the presence of hand-foot pairs of the same animal. The dimensions vary between 3 and 4 centimetres in length with a length / width ratio of approximately 1. There are no traces of nails. The length of the author's body was to be about 40 cm (Fig. 10c). What emerges this time? The fortifications were occupied by the Austro-Hungarian army, but the traces are very different from those of the mountain footwear "Bergschuhe". Austrian infantries were equipped with two main models of footwear. The first consisted of boots with pointed soles. The nails on the sole had the same arrangement as the Bergschuhe but the pointed nails on the margin were missing, replaced by a row of round nails and the heel was reinforced by a horseshoe plate. The second model, less frequent, was a boot with a more square sole and a squat point. In this case, the round-headed nails were arranged in rows transversal to the sole and did not reach the edge: a metal horseshoe reinforcement completed the heel. It is therefore evident that our traces are to be referred to infantry troops who were employed also in the defence of mountain posts. Animal traces belong to a small carnivore. Wild animals such as foxes and martens are excluded in shape and size. Even small domestic dogs are excluded due to morphology and the absence of nails. The closest similarities are with traces left by a medium-sized domestic feline.

The scene is lively: while the floor has just been finished by the workers, a soldier is busy between the kitchen and the warehouse, one of his fellow soldiers (part of a different contingent) looks out into the corridor, but realizing that the concrete is still fresh stops on the point of the boots and takes a step back; heedless of the two soldiers, a cat escapes from the kitchen taking refuge in the deepest part of the galleries.

4. CONCLUDING REMARKS

For just over thirty years, palaeoichnology has begun to recognize in human fossil footprints important support for understanding our history. The documentation of such finds in Italy is still sporadic and new finds are still scarce. Despite this, some of the sites recently studied confirm the great interpretative potential of the discipline. One of the most interesting aspects of the Roccamonfina site is, for example, the dynamic movement frozen over the time. The same can be said of the traces preserved in the internal corridors of the Grotta della Bàsura which, for the first time, clearly describe human exploration behaviour in complex environments. Even the most recent footsteps, linked to the chronology of the 20th century, are proving to be instruments with high educational potential in support of the narration of well-known historical events.

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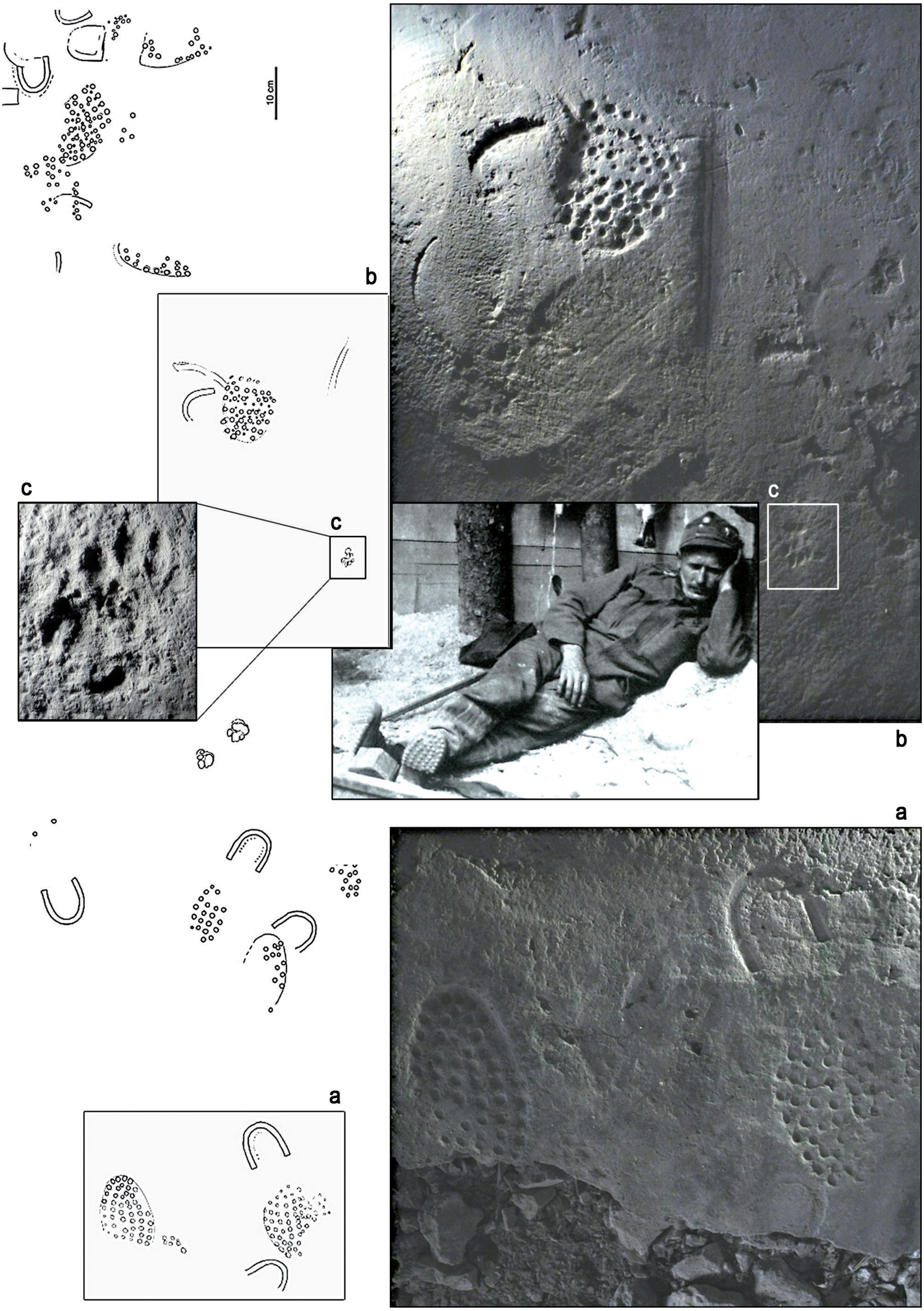

Fig. 10 - Monte Celva site (Trentino-Alto Adige). a) Shoes prints with regular rows of nails and reinforced by a sturdy metal plate; b) squat prints with a quadrangular tip and with rows of large and small nails; c) cat footprints; d) Austro-Hungarian infantry troops employed in the fortress.

REFERENCES

Acocella, A., 2013. Stile laterizio II. I laterizi cotti fra Cisalpina e Roma, Media MD, 2013, pp. 76.

Alexander R.Mc.N., 1984. Stride length and speed for adults, children, and fossil hominids. American Journal of Physical Anthropology 63, 23-27.

Almécija S., Smaers J.B., Jungers W.L., 2015. The evolution of human and ape hand proportions. Nature communications 6, 7717.

Altamura F., Bennett M.R., D'Août K., Gaudzinski-Windheuser S., Melis R.T., Reynolds S.C., Mussi M., 2018. Archaeology and ichnology at Gombore II-2, Melka Kunture,Ethiopia: everyday life of a mixedage hominin group 700,000 years ago. Nature: Scientific Reports 8, 2815.

Armirotti A., De Davide C., Wicks D., 2017. Scavi per l'ampliamento dell'Ospedale regionale Umberto Parini di Aosta: sintesi dei principali risultati. Bollettino della Soprintendenza per i beni e le attività culturali, Regione Valle d'Aosta 14, 14-31.

Appleton J.D., 1972. Petrogenesis of potassium rich lavas from the Roccamonfina Volcano, Roman region, Italy. Journal of Petrology 13, 425-456.

Arsuaga J.L., Carretero J.M., Lorenzo C., Gómez-Olivencia A., Pablos A., Rodríguez L., Martínez I., 2015. Postcranial morphology of the middle Pleistocene humans from Sima de los Huesos, Spain. Proceedings of the National Academy of Sciences 112, 11524-11529.

Arsuaga J.L., Martínez I., Arnold L.J., Aranburu A., Gracia-Téllez A., Sharp W.D., Poza-Rey E., 2014. Neandertal roots: Cranial and chronological evidence from Sima de los Huesos. Science 344, 1358-1363.

Ascenzi A., Biddittu I., Cassoli P.F., Segre A.G., Segre-Naldini E., 1996. A calvarium of late *Homo erectus* from Ceprano, Italy. Journal of Human Evolution 31, 409-423.

Ascenzi A., Mallegni F., Manzi G., Segre A.G., Segre-Naldini E., 2000. A reappraisal of Ceprano calvaria affinities with *Homo erectus*, after the new reconstruction. Journal of Human Evolution 39, 443-450.

Ashton N., Lewis S.G., De Groote I., Duffy S.M., Bates M., Bates R., Hoare P., Lewis M., Parfitt S.A., Peglar S., Williams C., Stringer, C., 2014. Hominin foot-prints from Early Pleistocene deposits at Happisburgh, UK. Plos One 9, e88329.

Avanzini M., 2003. Il primo alpinista: 350.000 anni fa sui fianchi di un vulcano. Natura Alpina 53, 1-5.

Avanzini M., 2011. A spasso nel tempo. Darwin 43, maggio/giugno 2011, Editoriale Darwin S.r.l, Roma, 16-21.

Avanzini M., 2012. Orme dal passato: storie di uomini in guerra. Archivio Trentino 1, 107-125.

Avanzini M., Bernardi M., Petti F.M., 2011. Soldier tracks in a First World War Fort (Valmorbiawerk, Trento, Italy). Ichnos 18, 72-78.

Avanzini M., Mietto P., De Angelis M., Panarello A., Rolandi G., 2008. The devil's trails: Middle Pleistocene human footprints preserved in a volcanoclastic deposit of southern Italy. Ichnos 15, 179-189.

Avanzini M., Mietto P., Rolandi G., 2003. Le orme dei più antichi europei emergono dal vulcano di Roccamonfina (Caserta). La Ricerca 25, 16.

Avanzini M., Romano M., Citton P., Salvador I., Arobba D., Caramiello R., Firpo M., Rellini I., Negrino F., Clementi L., Zunino M., Giannotti S., Starnini E., Conventi M., 2018. Icno-archeology of a human Palaeolithic ecosystem: the human and animal footprints in the Grotta della Bàsura (Toirano, Northern Italy). Alpine and Mediterranean Quaternary 31, 39-42.

Ballini A., Barberi F., Laurenzi M.A., Mezzetti F., Oddone M., Villa I.M., 1990. Chrono-Stratigraphy of Roccamonfina volcanic complex. In: Genesi e differenziazione del magmatismo potassico del bordo tirrenico: convegno autunnale: Ischia, 15-18 ottobre 1990. Società Italiana di Mineralogia e Petrologia, Abstract book, 18-19.

Ballini A., Barberi F., Laurenzi M.A., Mezzetti F., Villa I.M., 1989a. Nuovi dati sulla stratigrafia del vulcano di Roccamonfina. Bollettino G.N.V. 2, 533-556.

Ballini A., Frullani A., Mezzetti F., 1989b. La formazione piroclastica del Tufo Trachitico Bianco («White Trachytic Tuff»-WTT Auctorum) del vulcano di Roccamonfina. Bollettino Gruppo Nazionale Vulcanologia 2, 557-574.

Bennett M.R., Harris J.W.K., Richmond B.G., Braun D.R., Mbua E., Kiura P., Olago D., Kibunjia M., Omuombo C., Behrensmeyer A.K., Huddart D., Gonzalez S., 2009. Early hominin foot morphology based on 1,5-million-year-old footprints from Ileret, Kenya. Science 323, 1197-1201.

Blanc A.C., 1960. Le palline d'argilla della Grotta della Bàsura. Rivista di Studi Liguri 26, 9-25.

Blanc A.C., Pales L., Lamboglia N., 1960. Le Vestigia Umane nella Grotta della Bàsura a Toirano. Istituto Internazionale di Studi Liguri, Bordighera, Italia.

Brenda M.A., Rohreni M.A., 2006. Estimation of Stature from Foot and Shoe Length: Applications in Forensic Science. Internal report, Nebraska Wesleyan University, Department of Forensic Science. Available from: www.neiai.org/index.php.

Buryanov A., Kotiuk V., 2010. Proportions of Hand Segments. International Journal of Morphology 28, 755-758.

Bruzzone D., Bussallino M., Castello G., Maggiolo S., Rossi D., 2006. Measurement of the concentration of radon gas in the Toirano's caves (Liguria). Annali di Chimica 96, 515-524.

Burke T.R., 2002. Tell tale footprints: Determination of stature from foot length in forensic cases. California State Science Fair, Project Number J1003 (Abstract). Available from: http://www.usc.edu/CSSF/History/2002/Projects/J1003.pdf.

Carretero J.M., Rodríguez L., García-González R., Arsuaga J.L., Gómez-Olivencia A., Lorenzo C., Bonmatí A., Gracia A., Martínez I., Quam R., 2012. Stature estimation from complete long bones in the Middle Pleistocene humans from the Sima de los Huesos, Sierra de Atapuerca (Spain). Journal of Human Evolution 62, 242-255.

Charteris J., Wall J.C., Nottrodt J.W., 1982. Pliocene hominid gait: new interpretations based on available footprint data from Laetoli. American Journal of Physical Anthropology 58, 13-144.

Chiappella V.G., 1952. Orsi e uomini preistorici nella Grotta della Strega. Rivista del Comune di Genova 29, 22-29.

Chiesa R., Columbu A., Audra P., Bigot J.Y., 2019. Compte rendu de sorties des 7 et 8 avril 2019 dans les grottes de Toirano (Ligurie, Italie), http://alpespeleo.fr/com/comdiv/cr/2019-04-07.pdf.

Citton P., Romano M., Salvador I., Avanzini M., 2017. Reviewing the upper Pleistocene human footprints from the 'Sala dei Misteri' in the Grotta della Bàsura (Toirano, northern Italy) cave: An integrated morphometric and morpho-classificatory approach. Quaternary Science Reviews 169, 50-64.

Cole P.D., Guest J.E., Duncan A.M., Chester D.K., Bianchi R., 1992. Post-collapse volcanic history of calderas on a composite volcano: an example from Roccamonfina, southern Italy. Bulletin of Volcanology 54, 253-266.

Corrain C., 1977. I resti scheletrici della sepoltura epigravettiana del "Riparo Tagliente" in Valpantena (Verona). Bollettino del Museo Civico di Storia Naturale di Verona 4, 35-79.

Darowish M., Brenneman R., Bigger J., 2015. Dimensional analysis of the distal phalanx with consideration of distal interphalangeal joint arthrodesis using a headless compression screw. Hand 10, 100-104.

De Angelis M., 2009. Riscontri archivistici sull'origine del toponimo "Ciampate del diavolo". Unpublished report presented at the study conference "Ciampate del diavolo: mezzo passo nella leggenda... Un passo nella storia", Tora e Piccilli, 17 ottobre 2009.

De Lumley M.A., Giacobini G., 1985. Le impronte di piedi umani. Rivista di Studi Liguri 51, 362-366.

De Lumley H., Giacobini G., Vicino G., Yokoyama Y., 1984. New data concerning the dating and interpretation of human footprints present in the "Grotta della Bàsura" at Toirano (Savona, Northern Italy). Results of an International Round Table. Journal of Human Evolution 13, 537-540.

De Rita D., Giordano G., 1996. Volcanological and structural evolution of Roccamonfina volcano (Italy): origin of the summit caldera. In: McGuire W.J., Jones A.P., Neuberg J. (Eds.), Volcano Instability on the Earth and Other Planets. Geological Society, London, Special Publications 110, 209-224.

De Vos M., Maurina B., 2011. La villa romana di Isera. Ricerche e scavi (1973-2004), Museo Civico di Rovereto, CIII pub., Osiride, pp. 436.

Di Vincenzo F., Profico A., Bernardini F., Cerroni V., Dreossi D., Schlager S., Zaio P., Benazzi S., Biddittu I., Rubini M., Tuniz C., Manzi G., 2017. Digital reconstruction of the Ceprano calvarium (Italy), and implications for its interpretation. Scientific Reports 7, 13974.

Di Vito M.A., Zanella E., Gurioli L., Lanza R., Sulpizio R., Bishop J., Tema E., Boenzi G., Laforgia E., 2009. The Afragola settlement near Vesuvius, Italy: the destruction and abandonment of a Bronze Age village revealed by archaeology, volcanology and rock-magnetism. Earth and Planetary Science Letters 277, 408-421.

Fessler D.M.T., Haley K.J., Roshni D.L., 2005. Sexual dimorphism in foot length proportionate to stature. Annals of Human Biology 32, 44-59.

Fontana N., 2005. Valmorbiawerk, la fortezza incompiuta. Annali del Museo Storico Italiano della Guerra 12/13, 21-70.

Fontana N., 2004. Werk Dossaccio K.U.K. Storia di un forte corazzato di montagna (1886-1915), Ente Parco di Paneveggio-Pale di san Martino. Quaderni del Parco 4, 15-54.

Formicola V., Frayer D.W., Heller J.A., 1990. Bilateral absence of the lesser trochanter in a late epigravettian skeleton from arene candide (Italy). American Journal of Physical Anthropology 83, 425-437.

Garrido Varas C.E., Thompson T.J.U., 2011. Metric dimensions of the proximal phalanges of the human hand and their relationship to side, position, and asymmetry. Homo 62, 126-143.

Giacobini G., 2008. La Grotta della Bàsura e il "mito neandertaliano". Toirano e la grotta della Bàsura. Conoscere, conservare e gestire il patrimonio archeologico e paleontologico. Istituto Internazionale di Studi Liguri, Bordighera, Imperia, 21-27.

Giampaola D., Laforgia E., Amato L., Boenzi G., 2007. Linea A.V. - Afragola. Impronte di uomini e animali nel Bronzo Antico. Atti della XL Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria: Strategie di insediamento fra Lazio e Campania in età preistorica e protostorica, Roma, Napoli, Pompei, 30 novembre-3 dicembre 2005, vol. II, Firenze: Istituto Italiano di Preistoria e Protostoria, 928-931.

Giannetti B., 1979a. The geology of Roccamonfina caldera (Campanian Province, Italy). Giornale di Geologia 43, 187-206.

Giannetti B., 1979b. Studio geologico-petrografico della caldera del vulcano di Roccamonfina (Italia centro-meridionale). Bollettino del Servizio Geologico d'Italia 100, 311-374.

Gierliński G.D., Niedźwiedzki G., Lockley M.G., Athanassiou A., Fassoulas C., Dubicka Z., Boczarowski A., Bennett M.R., Ahlberg P.E., 2017. Possible hominin footprints from the late Miocene (c. 5.7 Ma) of Crete? Proceedings of the Geologists' Association 128, 697-710.

Giles E., Vallandingham P.H., 1991. Height estimation from foot and shoeprint length. Journal Forensic Science 36, 1134-1151.

Giorgetti D., González Muro X., 2011. Le fornaci romane di Alcamo. Rassegna di Studi e Ricerche 2006/2008. Catalogo dei materiali, pp. 288.

Grieve D.W., Gear R.J., 1966. The relationship between length of stride, step, frequency, time of swing and speed of walking for children and adults. Ergonomics 5, 379-399.

Helmuth H., 1974. Body height, foot size and the secular trend in growth. Zeitschrift für Morphologie und Anthropologie 66, 31-42.

Helmuth H., 1998. Body height, body mass and surface area of the Neandertals. Zeitschrift für Morphologie und Anthropologie 82, 1-12.

Kumar Agnihotri A., Purwar B., Googoolye K., Agnihotri S., Jeebun N., 2007. Estimation of stature by foot length. Journal of Forensic and Legal Medicine 14, 279-283.

Iulianis A., 1986. Tora e Piccilli. Storia, tradizioni e immagini. Nuove Edizioni ci.esse.ti., Napoli, pp. 12.

Lamboglia N., 1960. Le vestigia umane nella grotta della Bàsura a Toirano. Rivista di Studi Liguri 26, 1-5.

Laforgia E., Boenzi G., Amato L., Di Vito M.A., Fattore L., Stanzione M., Viglio F., 2009. The Vesuvian "Pomici di Avellino" eruption and Early Bronze Age settlement in the middle Clanis valley. Méditerranée 112, 101-107.

Lorenzo C., Pablos A., Carretero J.M., Huguet R., Valverdú J., Martinón-Torres M., Arsuaga J.L., Carbonell E., Bermúdez de Castro J.M., 2015. Early Pleistocene human hand phalanx from the Sima del Elefante (TE) cave site in Sierra de Atapuerca (Spain). Journal of Human Evolution 78, 114-121.

Luhr J.F., Giannetti B., 1987. The Brown Leucitic Tuff of Roccamonfina volcano (Roman Region, Italy). Contributions to Mineralogy and Petrology 95, 420-436.

Mallegni F., Fabbri P.F., 1995. The human skeletal remains from the Upper Palaeolithic burials found in Romito cave (Papasidero, Cosenza, Italy). Bulletins et Mémoires de la Société d'anthropologie de Paris 7, 99-137.

Mallegni F., Bertoldi F., Manolis S., 2000. Palaeobiology of two gravettian skeletons from veneri cave (Parabita, Puglia, Italy). Homo 51, 235-257.

Manzi G., 2016. Humans of the Middle Pleistocene: The controversial calvarium from Ceprano (Italy) and its significance for the origin and variability of *Homo heidelbergensis*. Quaternary International 411, 254-261.

Manzi G., Magri D., Milli S., Palombo M.R., Margari V., Celiberti V., Barbieri M., Barbieri M., Melis R.T., Rubini M., Ruffo M., 2010. The new chronology of the Ceprano calvarium (Italy). Journal of Human Evolution 59, 580-585.

Manzi G., Mallegni F., Ascenzi A., 2000. A cranium for the earliest Europeans: phylogenetic position of the hominid from Ceprano, Italy. Proceedings of the National Academy of Science 98, 1011-1016.

Marzke M.W., Marzke R.F., 2000. Evolution of the human hand: approaches to acquiring, analysing and interpreting the anatomical evidence. Journal of Anatomy 197, 121-140.

Mastrolorenzo G., Petrone P., Pappalardo L., Sheridan M.F., 2006. The Avellino 3780-yr-B.P. catastrophe as a worst-case scenario for a future eruption at Vesuvius. Proceedings of the National Academy of Sciences 103, 4366-4370.

McHenry H., 1992. Body size and proportions in early hominids. American Journal of Physical Anthropology 87, 407-431.

Menardi Noguera A., 1984. Nuove osservazioni sulla struttura del massiccio del Monte Carmo. Bollettino della Società Geologica Italiana 103, 189-203.

Mietto P., 2004. Macchè diavoli. Erano antenati in fuga. Ligabue Magazine 44, 146-157.

Mietto P., 2009. Le Ciampate del Diavolo dalla leggenda alla realtà scientifica. Atti Convegno Roccamonfina, 11 luglio 2009, Conoscere il Roccamonfina, 1. Il Geosito, Graficart, Formia, 39-46.

Mietto P., Avanzini M., Rolandi G., 2003. Human footprints in Pleistocene volcanic ash. Nature 422, 133.

Mietto P., Panarello A., Avanzini M., Sirano F., Santello L., Belvedere M., Rolandi G., De Angelis M., 2013. Ciampate del Diavolo. Le impronte dei primi uomini sul vulcano Roccamonfina. Spolia, Roma, pp. 43.

Molleson T.I., 1985. The antiquity of human footprints of Tana della Bàsura. Atti della tavola Rotonda "La Grotta preistorica della Bàsura", Toirano 11-13 novembre 1983. Rivista di Studi Liguri 51, 367-372.

Molleson T.I., Oakley K.P., Vogel J.C., 1972. The antiquity of human footprints of Tana della Bàsura. Journal of Human Evolution 1, 467-471.

Morse S.A., Bennett M.R., Liutkus-Pierce C., Thackeray F., McClymont J., Savage R., Crompton R.H., 2013. Holocene footprints in Namibia: the influence of substrate on footprint variability. American Journal of Physical Anthropology 151, 265-279.

Ozden H., Balci Y., Demirustu C., Turgut A., Ertugrul M., 2005. Stature and sex estimate using foot and shoe dimensions. Forensic Science International 147, 181-184.

Palombo M.R., Panarello A., Mietto P., 2018. Did elephants meet humans along the devil's path? A preliminary report. Alpine and Mediterranean Quaternary 31, 83-87.

Pales L., 1960. Le Vestigia Umane nella Grotta della Bàsura a Toirano. Rivista di Studi Liguri 24, 9-90.

Panarello A., 2005. Le impronte umane fossili di "Foresta": per una lettura storica del sito e una corretta interpretazione della scoperta scientifica. Intergraphica, Vairano Scalo, pp. 15.

Panarello A., 2016a. Il sito con impronte umane pleistoceniche di Foresta (vulcano di Roccamonfina, Caserta) quale laboratorio ideale per valutazioni oggettive sulle più antiche direttrici di transito umano e sui condizionamenti geomorfologici nelle logiche insediative. Ph.D Thesis, Università di Cassino e del Lazio Meridionale, Cassino, pp. 408.

Panarello A., 2016b. Elementi di Paleoicnologia degli ominidi. Armando Caramanica Editore, Marina di Minturno, pp. 228.

Panarello A., Mazzardo L., Mietto P., 2018. The devil's touch: a first dataset from what could be the oldest human handprint ever found (Central-Southern Italy). Alpine and Mediterranean Quaternary 31, 37-47.

Panarello A., Palombo M.R., Biddittu I., Mietto P., 2017b. Fifteen years along the "Devil's Trails": New data and Perspectives. Alpine and Mediterranean Quaternary 30, 137-154.

Panarello A., Palombo M.R., Biddittu I., Di Vito M.A., Farinaro G., Mietto P., 2020. On the devil tracks: unexpected news from Foresta ichnosite (Roccamonfina volcano, central Italy). Journal of Quaternary Science, doi: 10.1002/jqs.3186.

Panarello A., Santello L., Farinaro G., Bennet M.R., Mietto P., 2017a. Walking about the oldest human fossil pathway (Roccamonfina volcano, Central Italy)? Journal of Archaeological Science: Report 13, 476-490.

Paoli G., Parenti R., Sergi S., 1980. Gli scheletri mesolitici della caverna delle arene candide (Liguria). Memorie dell'Istituto Italiano di Paleontologia Umana Roma 3, 33-154.

Pastoors A., Lenssen-Erz T., Ciqae T., Kxunta U., Thao T., Bégouën R., Biesele M., Clottes J., 2015. Tracking in caves: experience based reading of pleistocene human footprints in french caves. Cambridge Archaeological Journal 25, 551-564.

Radicati di Brozolo F., Di Girolamo P., Turi B., Oddone M., 1988. $^{40}Ar/^{39}Ar$ and K-Ar dating of K-rich rocks from Roccamonfina volcano, Roman Comagmatic region, Italy.

Geochimica Cosmochimica Acta 52, 1435-1441.
Regione Valle d'Aosta, 2015. Aosta, scavi ampliamento Ospedale. Le impronte dei Salassi (http://www.regione.vda.it/cultura/patrimonio/siti_archeologici/news/ospedale_2014_i.aspx)
Righi I., Leonardi G., 2006. Austriaci in trincea nella Grande Guerra. Il sistema difensivo austro-ungarico dai manuali del Servizio Informazioni italiano. Rossato, Valdagno, pp. 164.
Robbins L.M., 1985. Footprints: Collection, Analysis, and Interpretation. Charles C. Thomas Publisher, Springfield, Illinois, pp. 244.
Robbins L.M., 1986. Estimating height and weight from size of footprints. Journal of Forensic Science 31, 143-152.
Romano M., Citton P., Salvador I., Arobba D., Rellini I., Firpo M., Negrino F., Zunino M., Starnini E., Avanzini M., 2019. A multidisciplinary approach to a unique Palaeolithic human ichnological record from Italy (Bàsura Cave). eLife 8, e45204. doi: 10.7554/eLife.45204.
Rouchon V., Gillot P.Y., Quidelleur X., Chiesa S., Floris B., 2008. Temporal evolution of the Roccamonfina volcanic complex (Pleistocene), Central Italy. Journal of Volcanology and Geothermal Research 177, 500-514.
Ruff C., 2002. Variation in human body size and shape. Annual Review of Anthropology 31, 211-232.
Saborit G., Casinos A., 2015. Parametric modeling of human gradient walking for predicting minimum energy expenditure. Computational and Mathematical Methods in Medicine 2015, 407156.
Saborit G., Mondanaro A., Melchionna M., Serio C., Carotenuto F., Tavani S., Modafferi M., Panarello A., Mietto P., Rook L., Raia P., Casinos A., 2019. A dynamic analysis of Middle Pleistocene human walking gait adjustment and control. Italian Journal of Geosciences 138, 231-238.
Santello L., 2010. Analysis of a trampled formation: the Brown Leucitic Tuff (Roccamonfina volcano, Southern Italy). Ph.D Thesis, Università di Padova, Italy, pp. 136.
Scaillet S., Vita-Scaillet G., Guillou H., 2008. Oldest human footprints dated by Ar/Ar. Earth and Planetary Science Letters 275, 320-325.
Sharpe K., Val Gelder L., 2006. The study of finger flutings. Cambridge Archaeological Journal 16, 281-295.
Starnini E., Arobba D., Avanzini M., Caramiello R., Citton P., Clementi L.C., Conventi M., De Pascale A., Firpo M., Giannotti S., Negrino F., Panizza F., Rellini I., Romano M., Salvador I., Zunino M., 2018. Di uomini e orsi. Archeo 404, 64-79.
Tongiorgi E., Lamboglia N., 1954. La Grotta di Toirano. Istituto Internazionale di Studi Liguri, Bordighera, Italia.
Topinard P., 1878. Anthropology. London: Chapman and Hall.
Villotte S., Samsel M., Sparacello V., 2017. The paleobiology of two adult skeletons from Baousso da Torre (Bausu da Ture) (Liguria, Italy): Implications for Gravettian lifestyle. Comptes Rendus Palevol 16, 462-473.
White T.D., 1980. Evolutionary implications of Pliocene hominid footprints. Science 208, 175-176.
Webb S., Cupper M.L., Robbins R., 2006. Pleistocene human footprints from the Willandra Lakes, southeastern Australia. Journal of Human Evolution 50, 405-413.
Will M., Pablos A., Stock J.T., 2017. Long-term patterns of body mass and stature evolution within the hominin lineage. Royal Society Open Science 4, 171339.