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Papers from the 1st Workshop

Archaeology in Africa

Potentials and perspectives on laboratory & fieldwork research

Edited by
Savino di Lernia and Marina Gallinaro

with contributions by
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with foreword by S. di Lernia

All'Insegna del Giglio

Arid **Z**one **A**rchaeology
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12. Ichnology and archaeology in the African record: a complementary approach

Flavio Altamura

Abstract. The discovery, in the late 1970s, of the Laetoli footprints in Tanzania (about 3.6 Ma) led the scientific community at large to recognize the importance of sites containing hominin fossil footprints. Since then, only a handful of such Lower and Middle Pleistocene tracksites have been found in Africa: Ileret and Koobi Fora in Kenya (1.5-1.4 Ma), Melka Kunture in Ethiopia (0.85 and 0.7 Ma), and Aalad-Amo in Eritea (ca. 0.8 Ma). Their scarcity is due to the fact that they were formed and preserved thanks to the chance combination of favorable paleoenvironmental conditions. However, the possibility that other sites may not have been detected because of the lack of adequate methodologies in traditional archeological research should not be underestimated. Fossil tracks can provide valuable data for reconstructing the environment, topography and ecology of the ancient landscape, and the ethology of its inhabitants, as well as insights on the behavior and biomechanical capabilities of the earliest hominin species. By recording *in situ* a fleeting biological activity, fossil tracks provide a level of detail that usually escapes other kinds of records, such as archeological and faunal records. This paper gives an overview of state-of-the-art methodologies used to detect, excavate, document and preserve these delicate stratigraphic features, citing examples from the oldest known sites. Its aim is to stimulate the development of 'ichnological awareness' in discussions of archeological research in Africa.
KeyWords. Fossil footprints; ichnology; archaeological research; Plio-Pleistocene; Africa.

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1. Introduction

Encountering a track of some kind is a common occurrence, and anyone can glean at least some information from it. But for populations of ethnographic interest – and surely for ancient communities of hunter-gatherers as well – observing, identifying and correctly interpreting tracks and footprints found on the ground would have been of the utmost importance for the subsistence and survival of human groups (Liebenberg 1990a, 1990b).
Ichnology (i.e. the study of tracks and traces left by living organisms) began as a branch of science that belonged in part to geology and in part to biology. It eventually became a specific area of study, though several theoretical and conceptual aspects are still being defined (Buatois and Mangano 2011). Over the past few decades, ichnology has proved that it can span across, hence can contribute to, various other disciplines, such as ethology and archeology, even forensic science (Buatois and Mangano 2011; Bennett and Morse 2014). The footprints discovered at Plio-Pleistocene archeological sites have attracted due consideration, especially in connection with the study of the evolution of human bipedalism. This aspect caught the attention of the scientific community after the discovery of extraordinary and extremely ancient (3.66 Ma, i.e. Million years Ago) footprints at Laetoli, in Tanzania (Leakey and Hay 1979; Leakey and Harris 1987).
The first book devoted solely to human fossil footprints was published only a few years ago (Bennett and Morse 2014). Finds in contexts dating from the Pleistocene to the Holocene have multiplied over the past couple of decades (e.g. Bustos *et al.* 2018; Helm *et al.* 2018; McLaren *et al.* 2018), as have theoretical works and reviews related to them (De Vos *et al.* 1998; Kim *et al.* 2008; Lockley *et al.* 2008; Bennett and Morse 2014; Lenssen-Erz and Pastoors 2017). Their conclusions have been corroborated by studies aimed at assessing the formation, preservation and meaning of these tracks made in different environments and by different human groups (e.g. Lockley and Rodríguez-de la Rosa 2009; Marty *et al.* 2009; D'Août *et al.* 2010; Morse *et al.* 2010, 2013; Hatala *et al.* 2013a, 2013b, 2016a, 2018; Bennett *et al.* 2013; Ruiz and Torices 2013; Pastoors *et al.* 2015; Grant *et al.* 2018; Wiseman and De Groote 2018; Wiseman *et al.* 2018; Zimmer *et al.* 2018; Bennett and Budka forthcoming 2019).
The study of human tracks has also given rise to a variety of more specific disciplines, for instance ichnoarcheology (Baucon *et al.* 2008) – i.e. the study of traces, including human footprints and coprolites, and bioturbation and bioerosion structures, found in archeological contexts or on archeological materials – and hominin ichnology (Kim *et al.* 2008), which besides footprints comprises all the different types of traces left by prehistoric humans in

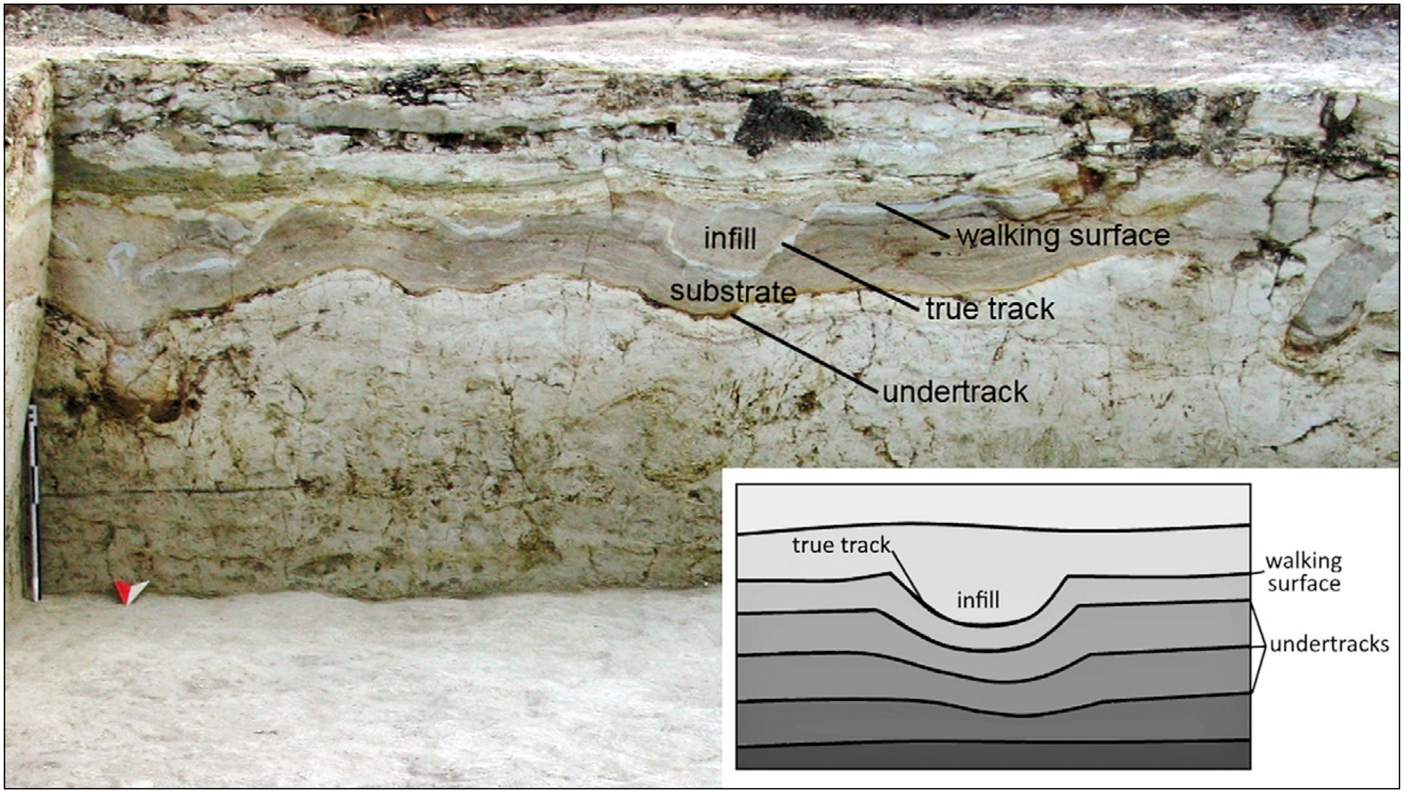

Fig. 12.1 – Gombore II-2. Sectioned bioturbation structures (hippo tracks) on the southern excavation cut made in 2013 (0.7 Ma) and their schematic representation (inset). Note the features typical of tracks: walking surface, track infill, true tracks and undertracks (Photo by the Author, Italian Archeological Mission at Melka Kunture and Balchit).

natural environments, such as marks left by butchering activities, lithic industry, structures and even artistic expressions (Kim *et al.* 2008). One gets the feeling that ichnology often trespasses into other specialist fields, such as taphonomy, archeology, anthropology and architecture, though it has undeniably given them valuable information.

2. What is a fossil track?

Tracks are biogenic structures formed by mechanical interaction between a living organism and a geological substrate. Generally speaking, tracks left by vertebrates are gravity-driven deformations of a soft substrate (Fig. 12.1). When an animal walks, stands or runs, it applies a downward force to the surface on which it moves, compressing it where its feet come in contact with it. If the pressure applied by the track-maker's foot exceeds the resistance of the substrate's sediments under it, they collapse, thereby deforming the substrate itself: the result is an excavated track (Buatois and Mangano 2011; Bennett and Morse 2014).

For this erosion to happen, the substrate must have certain features. The deposit's matrix and texture must be such as to make deformation possible, that is, the sediment must consist of fine-grained materials with a good degree of plasticity; the erosive phenomenon is intensified if these materials are associated with lithological sediments with contrasting characteristics (Laporte and Behrensmeyer 1980; Cohen *et al.* 1993; Ashley and Liutkus 2003).

The water content in a sediment is also a very important factor, because it influences the substrate's consistency and firmness, hence its ability to take and retain an impression. A waterlogged deposit usually will not be able to hold a track, because the sediments flow back in; conversely, a very dry substrate does not have the necessary plasticity to be deformable in the first place. Water content also strongly influences how well-defined a track will be and the amount of anatomical detail it will preserve. Experimental research (e.g. Milàn and Bromley 2007) has shown that if a sediment is not too wet, the substrate will preserve most of a track's contact surface, i.e. the surface that was in direct contact with the plantar surface of the track-maker's foot (true track, *sensu* Bennett and Morse 2014; Fig. 12.1). A substrate with a high water content, on the other hand, will be unable to preserve a track's original contact surface, so that, whether viewed from above or in cross-section, it will look like a poorly defined disruption.

The substrate's mechanical properties and its water content also influence the dynamics of pressure propagation. The compression of the surface layer also deforms the underlying layers, indirectly originating load structures and microfaults under the track's contact surface (Fig. 12.1); these features are proportional to the animal's weight and the speed and energy of the contact between plantar surface and substrate surface (undertrack, *sensu* Bennet and Morse 2014).

These factors, particularly substrate quality and consistency, influence a track's other morphological features as well. For instance, a marginal rim may be formed by the displacement of sediment during compression, or some substrate material may be dragged up and moved as the track-maker lifts its foot (respectively, displacement rim and track ejecta, *sensu* Bennett and Morse 2014).

If the substrate's characteristics are suitable, tracks can be impressed and preserved in many different environments: fluvial and fluvio-lacustrine systems, dunes and coastal mudflats, caves, volcanic areas, and so forth (Buoatois and Mangano 2011; Bennett and Morse 2014). As regards fluvial and fluvio-lacustrine contexts, tracked surfaces usually occur in the margin zones that border riverbanks and lakeshores, separating the submerged areas from the dry ones, because these are the only places where the water content of the sediments is adequate (Cohen *et al.* 1993).

Once a track has been impressed, another set of taphonomic factors comes into play, and rarely allow it to enter the fossil record. Present-day ichnological examples show that open-air track-bearing surfaces attest to biological activities that are rather close in time; the tracks are only a few days or weeks old, rather than months or years (Cohen *et al*. 1993; Roach *et al.* 2016). Tracks are very delicate stratigraphic elements, and are easily erased or eroded by weather events, geological phenomena or subsequent biological activity.

Hence, for tracks to be preserved, tracked surfaces must be quickly buried by other sedimentary deposits; the energy involved in the deposition process must be low, or the new sediments will erase the underlying tracks. Tracks can also be preserved when track-bearing surface hardens through desiccation and/or lithification, as is the case with volcanic ash (Laporte and Behrensmeyer 1980; Leakey and Harris 1987; Ashley and Liutkus 2003; Mietto *et al*. 2003; Bennett and Morse 2014). Clearly, for these bioturbation structures to remain more or less intact, it is also essential that post-depositional processes, such as compression, deformation and erosion, which could alter their morphology and dimensions – as is often the case when deposits are subjected to tectonic or metamorphic phenomena – be very limited (Bennett and Morse 2014).

3. Informative potential of fossil tracks

The importance of fossil tracks goes well beyond their mere preservation in a museum. Studies of their characteristics, associations and spatial distribution are excellent direct and indirect sources of information in archeological contexts (Cohen *et al.* 1993; Baucon *et al.* 2008; Buoatois and Mangano 2011; Bennett and Morse 2014). Ichnological research can thus reveal data that would otherwise be mostly "invisible," and that complement the information obtained from the archeological record in the usual way (e.g. via geological, archeozoological and techno-typological studies, and so on).

Because tracks form and are preserved in a number of environments only if certain conditions occur, their very existence already provides information on their paleoenvironmental and paleotopographic context, and on the substrate on which they were impressed (e.g. on the existence of paleosurfaces/walking surfaces; on the presence of bodies of water, hence the water content in the substrate sediments; on the rate of sediment deposition; on the desiccation and/or lithification rate, and so forth). Moreover, the presence of diagnostic tracks that can be attributed to specific taxa provides information on the behavior of single individuals or of entire groups (as attested at transit or congregation sites), as well as data on biological activities or on some of the track-maker's traits such as weight, age, walking speed, paleopathologies, and so forth. Faunal associations and their interactions with the environment, which may also be identified through spatial analysis and temporal markers (as in the case of overprints) can help us reconstruct in detail a site's paleobiological context and the chronological dynamics of its frequentation, which usually occurred over a rather narrow timeframe that coincided with the last phase of the context's lifetime before it was buried by new sediments.

It is also possible to compare species documented as fossils or whose presence is suggested by archeological materials, with those evidenced by their footprints (Cohen *et al.* 1993; Roach *et al.* 2016). Tracks do not move and are not formed over a length of time. Hence, they are evidence of a real frequentation that is limited in time and space, and they provide a sort of snapshot that captures a fleeting moment in a person's or animal's long-gone life. A fossil and/or archeological record, on the other hand, is much more affected by taphonomic and biological phenomena, and is therefore usually harder to anchor to any single episode of occupation (e.g. Altamura *et al.* 2018a). A large mammal bone, for instance, may have lain exposed on a surface for decades or have been carried a considerable distance by natural or biological agents before being buried by sediments and thus definitively entering the archeological record (Cohen *et al.* 1993; Haynes 2015). The quantity and quality of information that can be obtained from fossil footprints is obviously directly proportional to how large and how well-preserved the ichnological surfaces are, and to whether it's possible to identify any significant finds; for instance, it is better to find a trackway than single isolated tracks.

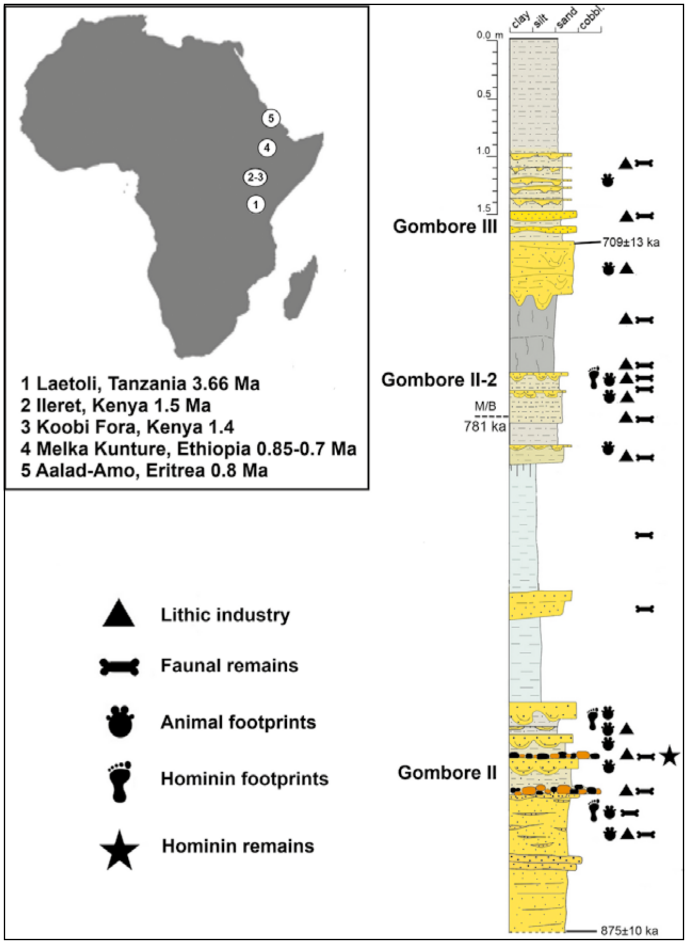

Fig 12.2 – The oldest known hominin-footprint sites in Africa (Pliocene-Middle Pleistocene). Simplified stratigraphic column of the upper part of the Gombore gully at Melka Kunture (late Early Pleistocene and Middle Pleistocene; modified after Mussi *et al.* 2016).

4. Human footprints in Africa between the Pliocene and the Middle Pleistocene

There are fewer than a dozen known sites containing human footprints predating the Upper Pleistocene in the whole world (Lockley *et al.* 2008; Bennett and Morse 2014). Africa holds the record for the oldest undisputed hominin footprints, though we must also take into account the possibility that the tracks recently discovered in Crete and dating to the Miocene (5.7 Ma) may prove to be hominin footprints (Gierliński *et al.* 2017). In any case, the oldest African hominin tracksites – i.e. the ones dating from before the Upper Pleistocene – can literally be counted on the fingers of one hand: Laetoli, Koobi Fora, Ileret and Melka Kunture. Finds have also been reported at Aalad-Amo, in Eritrea (Fig. 12.2). Though they are extremely rare, these finds have been of great value, for they have provided information about the track-makers' physiological and biomechanical characteristics, and insights into their behavior and their social and economic habits.

Analysis of the modes and characteristics of humans' bipedal locomotion, especially as regards the more ancient species, is of primary importance for understanding human evolution. From this standpoint, fossil footprints are a direct source of knowledge that is even more valuable in light of the fact that corresponding fossil remains are very rare. As regards species predating Neanderthals and anatomically modern humans, to date only a few dozen foot bones have been found (Pablos 2015; McNutt *et al.* 2018).

The oldest, and by far the best-known, human fossil footprints are those discovered at the Laetoli site in Tanzania, not far from Olduvai. The site consists of 18 large ichnological surfaces (Leakey and Hay 1979; Leakey and Harris 1987). Thousands of fossilized animal tracks have been found there over the years (Leakey and Harris 1987; Musiba *et al.* 2008). In the late 1970s, a trail of hominin footprints was found at Laetoli's Site G. These had been made by three individuals, and are generally attributed to *Australopithecus afa-*

rensis, this being to date the only species documented in the area by fossil remains found in contemporaneous deposits (Leakey and Harris 1987). Two more hominin trackways were recently discovered near Site G, and were found to belong to the same footprint horizon documented by Mary Leakey (Masao *et al*. 2017).

These footprints provided the first and oldest direct evidence of hominin bipedal locomotion, and led to in-depth studies that significantly advanced our understanding of hominin biomechanical evolution. They also provided important information on aspects such as the track-makers' walking speed and their height and weight, with implications concerning the variability of sexual dimorphism within a given species (Day and Wickens 1980; Charteris *et al.* 1981; Leakey and Harris 1987; Raichlen *et al*. 2008, 2010; Crompton *et al.* 2012; Hatala *et al*. 2016b; Masao *et al.* 2017; Raichlen and Gordon 2017).

The tracks were imprinted 3.66 Ma ago in a layer of volcanic ash which may have erupted from the Sadiman volcano (Deino 2011; Zaitsev *et al.* 2011). Rain had fallen on the ash layer's surface, making it wet and soft enough to receive and retain the tracks made by the hominins that walked on it shortly after the rainfall. Subsequent pyroclastic falls buried the footprints, protecting and preserving them (Hay 1987). Other hominin tracks found in Africa are much more recent. The track sites at Ileret and Koobi Fora date from between 1.5 and 1.4 Ma; the two sites lie at a distance of 45 km from each other in the Turkana Basin, in northern Kenya (Bennett and Morse 2014).

At Ileret, at least two track-bearing horizons were discovered in a fluvio-lacustrine deposit (FwJj14E) about 9 meters thick and dated at 1.52-1.53 Ma. The older track surface, at the bottom of the sequence, has yielded five human footprints on two superimposed levels. The more recent one, which lies higher up in the stratigraphic sequence, consists of several isolated prints and a trail of 9 footprints made by at least two individuals (Bennett *et al.* 2009; Dingwall *et al.* 2013). The tracks were imprinted on layers of silt and sand, and are associated with a rich palimpsest of animal tracks (mainly bovid and avian); these features probably indicate that the paleoenvironment was a delta plain or a lakeside area subjected to intermittent low-energy flooding and sediment deposition. Morphometric analyses of the Ileret footprints have shown that they were made by tall and heavy-set individuals (Bennett and Morse 2014). Bennett *et al.* (2009) tentatively attributed them to *Homo erectus*, while Dingwall *et al.* (2013) suggested that they could have been made by *Paranthropus boisei*.

Research currently under way at the Ileret site has led to the discovery of many other paleosurfaces bearing human and animal tracks (Roach *et al.* 2016). A total of 481 prints, 97 of them human, have been identified to date in five excavation areas. Studies now available indicate that humans moved together in groups, usually along the lakeshore (Hatala *et al.* 2016c, 2017; Roach *et al.* 2016).

At Koobi Fora, a track surface was uncovered on a silty-sandy layer located below a tuff dated at 1.43 Ma. The excavated surface contains 89 impressions made by hippopotamuses, other tetrapods and birds (Behrensemeyer and Laporte 1981; Bennett *et al.* 2009; Bennett and Morse 2014). There are only seven human footprints, lined up along a NW-SE axis; this trail appears to have been made by a single individual. Unfortunately, the prints are poorly defined and do not preserve any significant anatomical details. When the prints were first discovered they were attributed to *Homo erectus* (Behrensemeyer and Laporte 1981); the results of a recent re-excavation of the prints seem to confirm this interpretation (Bennett *et al.* 2009). Based on sedimentological analysis and the presence of tracks made by aquatic birds, most likely the tracked surface was located in a fluvio-lacustrine environment, perhaps a very shallow body of water. Recent excavations of the same paleosurface less than a hundred meters away have unearthed several other track horizons, probably belonging to the same paleoenvironmental context. A great number of hippo tracks were found here, but to date no hominin footprints (Bennett *et al.* 2014).

In June 2016, researchers announced that they had found several fossilized hominin footprints at the Aalad-Amo site, in Eritrea's Danakil desert. No detailed study has as yet been published; the only preliminary information available has been given via press releases and a few interviews (e.g. https://www.uniroma1.it/it/node/26082). The tracked surface, covering several square meters, was brought to light by erosion at the bottom of a dried-out stream bed. About a dozen footprints are preserved on the surface of a sandy-silty layer dating to 0.8 Ma. They may have been made by at least two individuals moving from north to south, and are associated with ungulate tracks. Studies are in progress; however, based on the dating of the deposit, the prints have been tentatively attributed to *Homo erectus*.

4.1 A case study: Melka Kunture

The cluster of archeological sites that make up Melka Kunture, about 50 km south of Addis Ababa, in the Ethiopian highlands (Fig. 12.2), has been undergoing extensive excavation since the 1960s, first by a French team and, then for the past twenty years or so, by the Italian Archeological Mission nowadays led by Margherita Mussi. In the past few years, much of its work has focused on ichnological research, which has contributed significantly to the characterization and reconstruction of the area's complex stratigraphic sequence.

The identification of track-bearing horizons at such an important site – in part through fieldwork, in part by reviewing documentation from previous excavations – has highlighted the complementary nature of ichnology and archeology, and made Melka Kunture an especially fruitful case for testing the potential of this interdisciplinary approach.

Melka Kunture is located at 2000 m asl in the Upper Awash basin, and spreads over an area of 100 sq. kilometres area. During the Pleistocene, conditions here were ideal for the formation and preservation of track-bearing surfaces. The environment was mostly fluvio-lacustrine, with ponds, swamps and meandering or braided fluvial systems. The paleolandscape's hydrographic and geomorphological features were periodically altered by the accumulation of ash and pyroclastic falls ejected by volcanic eruptions about 30 km away (Chavaillon and Piperno 2004). These volcanic deposits have made it possible to establish a detailed system of absolute ages through $^{40}Ar/^{39}Ar$ dating, which in turn makes it possible to establish – either directly or through stratigraphic correlation – a chronological framework for the main sequences in the area (Morgan *et al.* 2012). Paleoenvironmental data are also available for many sites (Bonnefille *et al.* 2018).

More than 70 archeological surfaces attest to human occupation of the area starting about 1.8 Ma; the oldest sites, located at the same level as the Awash River's current bed, have yielded evolved Oldowan techno-complexes. The Acheulean is very abundant, and is present in its Early, Middle and Late phases in various localities. Archeological levels and finds from the Middle and Late Stone Age show that the area continued to be much frequented during the Upper Pleistocene and the Holocene as well (Chavaillon and Piperno 2004; Morgan *et al.* 2012; Gallotti and Mussi 2018).

In 2013, during excavations at the Gombore II-2 site (0.7 Ma), archeologists noted the presence of some unusual geological features and suspected them to be bioturbation structures (Fig. 12.1). When the ichnological nature of these features was confirmed – the very first Pleistocene fossil tracks recorded in Ethiopia – a specific search for footprints was initiated, both at that site (2013-2015) and at other nearby sites in the Gombore gully (2013-2017). As a result, a number of fossil footprints were found, especially in most of the higher portion of the gully's geo-archeological sequence, which dates from the end of the Early to the Middle Pleistocene (Fig. 12.2). The prints were documented by means of natural and man-made sections and test excavations at several sites: Gombore II-OAM and Gombore II-1 (0.85 Ma), Gombore II-2 and Gombore X (0.7 Ma), and Gombore III (0.6-0.4 Ma) (Mussi *et al*. 2016, 2017; Altamura *et al*. 2017, 2018a, 2018b).

Moreover, field surveys and a review of published data and of unpublished documentation from the Archeological Mission's archive pointed to the presence of more track-bearing horizons at other Melka Kunture sites (Altamura 2017), specifically in the Kella gully (1.8-1.7 Ma), at Gombore I and Gombore Iγ (c. 1.5-1.2 Ma), at Garba IVD (1.5-1.4 Ma) and in the Garba gully (1.3-1 Ma, see also Raynal *et al.* 2004: 150), and at Garba XII (1.3-1.1 Ma), Simbiro III (ca. 1 Ma) and Garba I (0,6 Ma).

Research conducted in the upper part of the Gombore gully yielded the most significant results of this new methodological approach. The gully's geo-archeological sequence (Fig. 12.2) contains many levels bearing human traces embedded in fine-grained sediments of fluvio-lacustrine origin. At the base is a tuff $^{40}Ar/^{39}Ar$ dated to 0.87 Ma, while the ignimbrite at the top of the sequence pertains to an eruption that occurred 0.7 Ma. The Matuyama-Brunhes magnetostratigraphic boundary (ca. 0.78 Ma) was identified in the sequence between these two tephra markers (Morgan *et al.* 2012; Tamrat *et al.* 2013; Mussi *et al*. 2016; Altamura *et al.* 2017, 2018a). Above the older tuff (0.87 Ma) is an extensive archeological level (about 1,000 sq. meters) which dates from about 0.85 Ma and has been explored at various times in a number of sectors (Chavaillon and Piperno 2004; Gallotti *et al.* 2010; Altamura and Mussi 2017). The main archeological layer, which has yielded thousands of artifacts and faunal remains, including two cranial fragments attributed to an early form of *Homo heidelbergensis* (Gallotti *et al.* 2010; Mussi *et al.* 2016; Profico *et al.* 2016), is sandwiched between two deposits consisting of silts alternating with fine sands, the upper one being over one meter thick.

Many track-bearing surfaces were documented at the interfaces between the alternating silt and sand layers (which except for these tracks would be considered sterile), both under and above the main archeological level. The tracks were first noted during surveys of the exposed cuts at Gombore II OAM (Fig. 12.3) and in old photographs and drawings made at Gombore II OAM and Gombore II-1, which showed stratigraphic disruptions which had not been identified correctly (Mussi *et al.* 2016: SI figs. 6-7; Altamura and Mussi 2017).

These structures appeared to be gaps and hollows, usually only a few centimeters wide, which had been filled up by the overlying sands o silts. The bottom of most of these structures had convex morphologies, often with a number of lobes, that had penetrated a few centimeters deep into the underlying sediment (Fig.

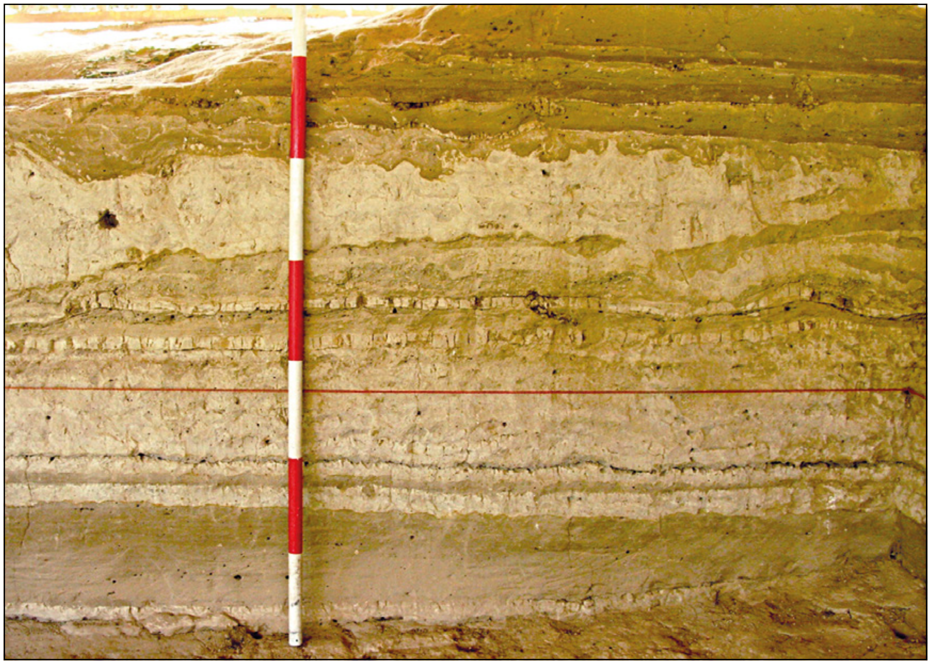

Fig. 12.3 – The southern excavation cut at the Gombore II OAM site at Melka Kunture (ca. 0.85 Ma). Many bioturbation structures (footprints), cross-sectioned vertically, are located at the contact surface between the silt and fine-sand layers (Photo by the Author, Italian Archeological Mission at Melka Kunture and Balchit).

12.3). Other depressions, over 20 cm wide, were also observed; they were identified as footprints of *Hippopotamus* sp. (Mussi *et al.* 2016; Altamura and Mussi 2017).

In 2015, a test excavation (1 sq. meter) was made in the northern part of Gombore II OAM on an exposed silt deposit located below the main archeological layer, hence can dated to between 0.87 and 0.85 Ma or earlier. The excavation revealed a densely packed palimpsest of vertebrate tracks, including one human footprint made by the right foot of a young individual (Altamura and Mussi 2017). In 2017, another test excavation of 2 sq. meters was made in the SW area of the same site, exploring the fluvio-lacustrine sequence (1.3 m thick) that overlies the archeological level. The findings (still being studied) are very interesting: the surfaces of all thirteen silty and silty-sandy layers intercepted by the excavation contain fossil imprints made by vertebrates, including hominins, and by invertebrates (Altamura *et al.* 2018b).

Above these levels lies a massive clay deposit (about 2 m thick), and above it more alternating silt and sand layers formed in a fluvio-lacustrine environment. As recorded both at Gombore II-2 and at the natural cut at Gombore X (about 30 m farther south), this portion of the stratigraphic sequence, dated between 0.78 and 0.7 Ma, contains bioturbations. Excavations conducted in 2013-2015 at the same level as the butchering site found at Gombore II-2 exposed a large track-bearing paleosurface, extending over about 35 sq. meters on a silty-sandy layer (Altamura *et al.* 2018a). Thanks to the overlying ignimbrite layer (1 m thick) which sealed and protected it, this surface is well preserved and contains hundreds of tracks made by large and small mammals (hippos, bovids, equids, suids and others) and birds that were walking through or congregating at the site (Fig. 12.4). Eleven hominin footprints were also found: they had been made by adults and children, some very young (about one year old).

In direct stratigraphic association with this surface is a rich archeological and paleontological record, the first one ever found in an ichnological context this old. Finds show that humans occupied the site for a relatively short time, perhaps only one season, settling at the edge of a body of water to carry out specific activities, including butchering hippo carcasses (several hippo bones found here bear cut marks). The fact that in this context infant tracks were found together with those of older individuals suggests that children were present when adults performed day-to-day activities such as tool-knapping and butchering, and may

Fig. 12.4 – Gombore II-2. Detail of the 0.7 Ma track surface 2015 excavation (Photo by the Author, Italian Archeological Mission at Melka Kunture and Balchit).

indicate that children had to start learning these skills at a very young age (Altamura *et al.* 2018a).

On the top of the tuff layer that seals this paleosurface, archeologists discovered a fossil trackway and exposed a portion over 6 m long (Altamura *et al.* 2017). It is a channel-like erosion structure, with a concave bottom up to 2 meters wide filled with large bioturbation structures (Fig. 12.5). Other similar structures, isolated or in a line, were found elsewhere on the tuff's surface and along the excavation walls. These elliptical structures, some as them as much as 50 cm deep, had filled with sand and silt from the overlying deposits. To study them, researchers either emptied out their infill to expose the tracks' original contact surfaces (true tracks) or isolated them by scraping away the surrounding tuff to obtain free-standing positive casts (natural track casts, Fig. 12.5).

The morphology of the tracks indicate that they were made by *Hippopotamus* cf. *amphibius*. Their study gave a good idea of the shape and size of the soft tissues of these animals' feet, and suggested that by the beginning of the Middle Pleistocene hippos apparently behaved just as they do today (Altamura *et al.* 2017). Similar footprints were also found at Gombore X, in a similar chrono-stratigraphic context (volcanic sands and tuff, dated 0.7 Ma). The 0.7 Ma-tuff is topped by more sand and silt layers; they too contain many footprints visible along excavation cuts and tests at Gombore III (0.6-0.4 Ma) (Mussi *et al*. 2016, 2017; Altamura 2017).

5. Investigation methods and constraints on research

The abundance of track-bearing horizons identified in these past few years at Melka Kunture shows how focusing on ichnological features can open up important new lines of research even when dealing with deposits that have already been well investigated from other standpoints. Excavations at Melka Kunture started in 1963, but fossil tracks there were not studied at all until very recently. We can only guess how many and what kind of ichnological data have been lost or have not been adequately considered over the decades here and at many other African sites.

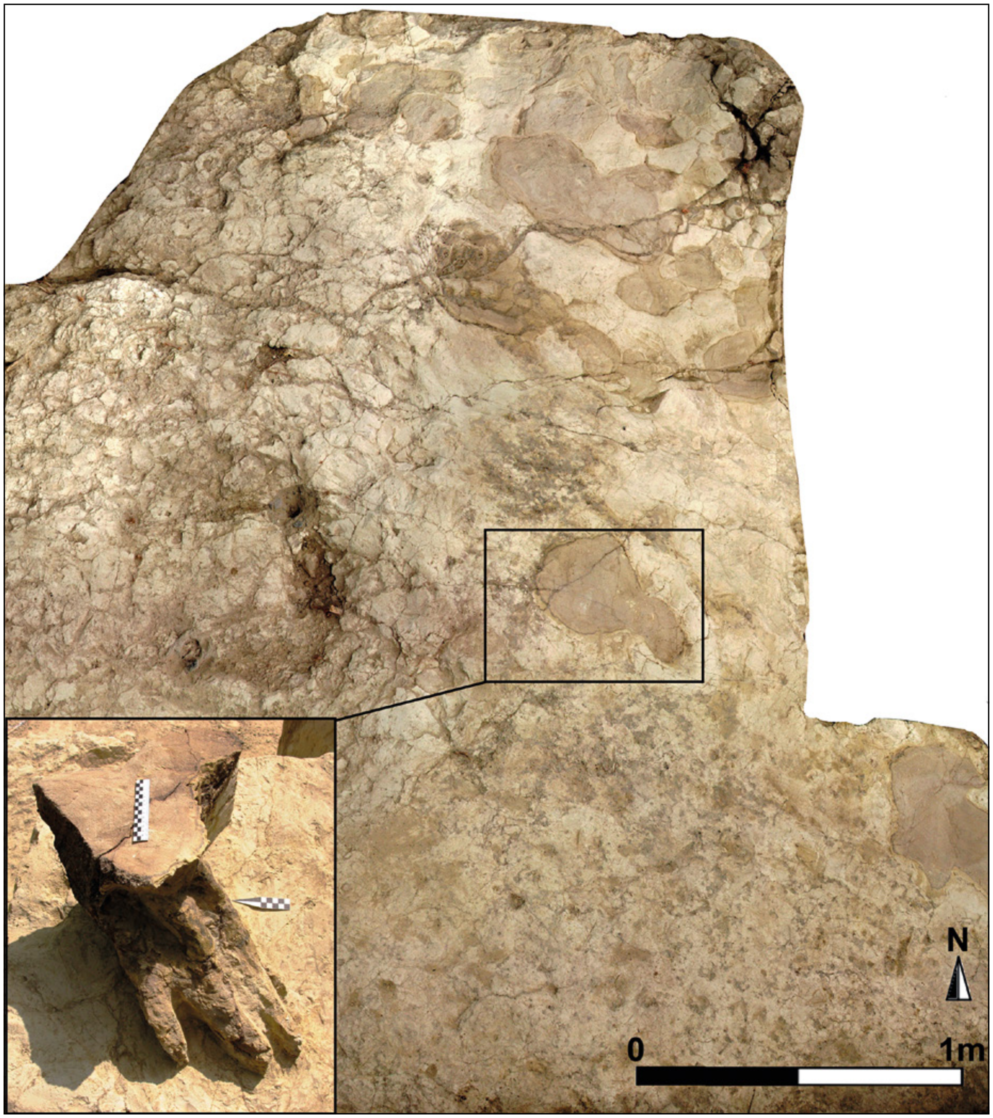

Fig. 12.5 – Gombore II-2. Orthophoto plane of the western portion of the fossil hippo trail (0.7 Ma) found on top of an ignimbrite layer. At the bottom of the channel-like trackway are large sand-filled bioturbation structures. Inset: a natural track cast of a hippo footprint obtained by freeing the infill from the surrounding matrix (photos by the Author, Italian Archeological Mission at Melka Kunture and Balchit; orthophoto plane elaborated by Kristian D'Août).

While it is true that fossil footprints are rare, their scarcity may be due less to a lack of finds than to a lack of awareness, attention and adequate investigation methodologies in traditional archeological research. If we consider that a moderately active person takes about 7,500 steps a day (https://royalsociety.org/science-events-and-lectures/2017/summer-science-exhibition/exhibits/dinosaurs-to-forensics/), and that he or she will normally live several decades, average people may take hundreds of millions of steps in their lifetime. Of course, not all steps leave a footprint, and very few footprints make it into the geo-archeological record. But it is very likely that evidence of this kind is much more abundant than one would think, especially in places whose paleoenvironmental conditions would have facilitated their formation.

Fig. 12.6 – Gombore II-2. Detail of the track surface (0.7 Ma) during excavation (top) and after removal (bottom) of the track infills (Photos by the Author, Italian Archeological Mission at Melka Kunture and Balchit).

It is therefore important that archeologists be aware that they may encounter these delicate structures when doing fieldwork and (as we have seen at Melka Kunture) when reviewing archival documents.

There are two circumstances in which fossil footprints may be identified in the field: at open-air sites where they have been uncovered by erosion, as at Laetoli and Aalad-Amo, or during stratigraphic excavations, as at Melka Kunture, Ileret and Koobi Fora. In the first case, for exposed footprints not to be subjected to severe degradation and therefore to still be recognizable, it is important that the tracked surface be much more resistant to erosion than are the sediments that seal it.

During stratigraphic excavations, cuts must be examined with great care in order not to miss any stratigraphic disruptions (small hollows, gaps, gravity-driven deformations); being located at contact surfaces between deposits, they could be attributed to trampling (Fig. 12.3). If any such disruptions are observed, test excavations can be made to expose the original surfaces of the layers and check whether any gaps have been filled with materials whose physical features and texture differ from those of the substrate sediment.

Exposing footprints – i.e. the contact surfaces between the track-maker's foot and the substrate (true tracks) – is very time – and energy-consuming. It can be done as a normal micro-stratigraphic excavation (Fig. 12.6), using small tools such as scalpels and paintbrushes, taking care to remove only the track's infill and to correctly isolate the footprint's walls and base, which constitute a 'negative' stratigraphic unit ("cut"). At Melka Kunture, emptying out a medium-sized print (about 15×15 cm) could take several hours. Results are best when the physical characteristics (consistency, color, matrix, etc.) of the substrate and of the infill are different enough that one can distinguish clearly between the two (Fig. 12.6). At Melka Kunture, for instance, the substrate and the infill of a track were sometimes so similar (clay on clay, silt-sand on silt-sand), or the substrate had been so disrupted, that it was impossible to distinguish the track's walls from its infill, hence to expose the original imprint. The same situation occurs when tracks were imprinted on sediments that were not firm enough or were too wet for any preserved tracks to be well defined. In such cases, all one can do is to simply note and record their presence.

Exposing tracks is usually a very delicate operation that should be carried out only by specialists who are also experienced in stratigraphic excavation. Choices must be made about which methods to use to expose and remove track infills, especially when dealing with surfaces containing complex palimpsests (overprinting, *sensu* Bennett and Morse 2014); in these cases, operators must decide the order in which to remove superimposed infills, and must document all the excavation stages.

In the case of large tracks with compact or lithified infills, operators may choose to obtain natural track casts (Fig. 12.5). As explained above, this is done by removing the matrix from around the infilled track. This should be done gradually, from the top down, taking care to stabilize the sediment as one proceeds. The resulting block can then be detached and stored. Besides fully preserving the track's original morphology, this procedure also makes it easier to display the track in a museum.

The traditional methods used to document fossil tracks are drawing and photographing (e.g. Leakey 1987). In recent years, new technologies have proved very useful, especially laser scanning and photogrammetry (Bennett *et al.* 2013, 2016; Bennett and Morse 2014; Belvedere *et al.* 2018; Zimmer *et al.* 2018; Bennett and Budka forthcoming 2019). Using digital data capture and analysis tools such as DigTrace (a freeware solution available at www.digtrace.co.uk), one can create 3D models whose degree of accuracy and detail is vastly superior to what can be rendered in a traditional drawing or photograph. However, these methods can require considerable financial resources and logistic and technical skills (Bennett and Morse 2014), especially when researchers are in a site in a country outside the so-called industrialized world.

These technologies are also extremely useful from the conservation standpoint. Track preservation is a major issue. If a fossil track-bearing surface is located on non lithified sediments, for instance, conservation problems arise as soon it is unearthed, since it will obviously be subjected thereafter to normal deterioration processes (Bennett *et al.* 2013; Wiseman and De Groote 2018; Zimmer *et al.* 2018). To date no definitive protocol for the preservation of track-bearing surfaces on soft sub-layers has been developed. Consolidating the surface with resins such as Paraloid is only a temporary measure. It is also possible to take a cast of the surface, or even remove it altogether. At present, the best way to preserve fossil-track data is to document them by means of advanced technologies (Bennett *et al.* 2014). In the future, 3D digital models could be used to create any number of replicas in other materials (resins, plaster and so forth) through 3D printing, a technology that is being continually developed and improved. Be that as it may, preservation remains a problem that should be solved as soon as possible. Unfortunately, many important ichnological sites are in countries that lack the necessary skills and resources to implement conservation projects or to build adequate protective or museum structures. Indeed, the scientific community has repeatedly sounded the alarm about the critical state in which the Laetoli footprints have been allowed to fall (Dalton 2008; Musiba *et al.* 2008).

6. Conclusions

Ichnology's interdisciplinary character makes it particularly suitable to complement archeological disciplines. Hence, archeologists should seek to establish long-lasting collaborations and projects with ichnologists (as they do with specialists in other fields). Each side would thus give the other a wealth of information that would normally go unnoticed in a traditional archeological record. This kind of collaboration has already borne fruit at Melka Kunture, where the identification of track-bearing surfaces helped researchers reconstruct certain aspects of the palaeolandscape and revealed the existence of 'ghost' biological elements. There is now evidence that layers that used to be thought sterile from the archeological standpoint – that is, they had not yielded any lithical or faunal material – were in fact intensely frequented by various mammal species, hominins included, and other vertebrates.

Ichnological research proved to be very important – often providing the only information available – for reconstructing the archeological contexts found in the Gombore gully's sequence (Fig. 12.2). Moreover, this kind of research can be associated and integrated with other types of approach, fostering collaborations with researchers from other branches of natural science, such as archaeozoology, geology and palynology (see for example Mussi *et al.* 2016).

It should be borne in mind that archeologists generally do not have in-depth knowledge of subjects such as ichnology and biomechanics, and must therefore turn to specialists. In any case, they have an ethical and material duty to extract the largest possible amount of data from an activity – stratigraphic excavation – that is destructive by nature. It is therefore of the greatest importance that archeologists be aware that they may come upon track-bearing surfaces and should know how to deal with them and how to document them in the best way possible. In other words, archeologists should not only look at the finds they unearth, but also cast their eyes on the sediment that contained them. It's worth the effort: fossil tracks have great potential both for the scientific information they provide and their 'musealization', not to mention the strong impact their discovery has on the public at large.

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